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WATERPROOFING UNDERGROUND CONCRETE STRUCTURES

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BY

TIM BIGGINS

A REPORT PRESENTED TO THE GRADUATE COMMITTEE
OF THE DEPARTMENT OF CIVIL ENGINEERING IN
THE PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF ENGINEERING

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Acknowledgements

This report is dedicated to my wife, Brenda, and my daughter Stacey for their patience, love and support while I dedicated myself to the task at hand.

I would like to thank Dr. John Daugherty of the Owens Corning Fiberglass Corporation Technical Center for his assistance in helping me sort out the vast array of waterproofing products and manufacturer claims into fact and fiction.

A special thanks is extended to Rear Admiral A. K. Riffey, Captain G.B. Estes and Commander Ron Kechter of the Civil Engineer Corps, United States Navy for their steadfast faith in my engineering abilities during the selection of waterproofing systems for the Atlantic based Strategic Weapons Missile Production Facilities at the Naval Submarine Base, Kingsbay, Georgia.

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CHAPTER ONE
GENERAL INFORMATION

1.1 Introduction

On March 6, 1986 I was assigned to the Officer in Charge of Construction, Trident at the Naval Submarine Base in Kingsbay, Georgia. As a Navy Officer in the Civil Engineer Corps my duties included the administration and management of over $100 Million in contracts for the construction of the D-5 Trident Missile Production Facilities. These facilities included the construction of 66 Missile Magazines, a Re-enrty Body Complex, Security Buildings, and two Vertical Missile Packaging Buildings.

The construction was located aboard the base in an area that had been reclaimed from the surrounding swamps. All of the Missile Production Facilities, because of their explosive potential, were required to be hardened earth covered concrete structures. Because the water table was located only one foot below the ground level these structures were constructed from on grade slabs and when completed they were covered with earth. In addition, several missile silos were needed that required the construction of pits extending 60 feet below grade.

During the design phase considerable emphasis was given to keeping the facilities waterproof. This concern emanated from the required missile storage environment of less than 40% relative humidity. Given the naturally high ambient humidity of south Georgia, the prevailing rains and wind, it's proximity to the coastline, underground construction and the swamp like location it was imperative

that the facilities remain free of outside water for the Heating, Ventilation, and Air Conditioning (HVAC) to maintain the required 40% relative humidity. However, this goal appeared easier to achieve on paper than in practice as some waterproofing systems preformed as intended, while others failed resulting in substantial cost increases and schedule delays.

Thus began my education in the field of Waterproofing which is an area of engineering that is not very well known or understood by either designers or contractors and yet is a leading cause of failures in building construction today (1). In fact, chances are that if you required expertise in waterproofing of an underground structure you would be referred to either a roofer or a paint specialist. However, neither of these specialists has the unique knowledge, training or experience required to ensure that underground structures remain dry throughout their design life.

Accordingly, I have taken this opportunity to define the role of waterproofing; the reasons for waterproofing failures; to explain the various waterproofing types and their uses; and to identify the most typical waterproofing problems and their solutions. The primary task of this paper therefore, is to provide some background for the selection of waterproofing systems for underground structures. Because of the extensive nature of this subject I have confined my coverage to the waterproofing of underground concrete structures such as utility tunnels, communication vaults, basements, elevator pits, missile silos, and control rooms.

1.2 Reasons for Waterproofing

The way in which water flows over and around a structure has not until recently been considered a subject worthy of study by many engineers and architects. In the past the use of standard details and specifications has saved the designer from having to consider very deeply what is really happening when water encompasses a building. Now with the increasing use of underground structures due to trends in energy conservation, and advances in power and communication technologies the field of waterproofing has taken on increasing importance (2).

All buildings regardless of their shortcomings are required to possess two fundamental characteristics. They should be structurally sound and they should exclude water. In the case of underground concrete structures which are usually surrounded by moisture the need to keep the water out is critical. Probably the most common example of underground concrete structures that leak is the typical home basement. Although fairly sophisticated techniques and expense are employed the problem of leaking basements still exists to a great degree. In fact 85 percent of builders report that they frequently have problems with leaking basements (3). A third of these same builders reported that the leakage problem was heavy indicating standing water on the floor. My own experience as a former Public Works Officer at two Naval Bases also supports these findings and lends strong support to the need for an increased awareness of these problems and solutions.

The factors most often cited as the leading causes of leakage are poor control of surface and underground water, improper selection of the most suitable material, inadequate detailing by designers, poor workmanship, defective materials, inadequate supervision, and poor construction procedures. Some people also blame architectural education for ignoring this facet of building construction while others blame lower standards of construction on site. Most importantly, relevant standards on waterproofing materials and construction are in many cases out-of-date , out-of-touch and too generalized to be sufficiently useful (4). I found this to be the case in my own research of this subject.

By far the most current, detailed, and useful literature that I have found on the subject of waterproofing has been through the manufactures of waterproofing products and systems. However, this material is obviously biased towards the manufacturer and requires the designer to expend an extraordinary amount of time comparing one manufacture's products against another. The evaluation of a waterproofing product's suitability for performance, application, and general conditions requires the designer to be familiar with a wide variety of engineering disciplines such as chemistry, material sciences, rheology, hydrology, structures and must also possess a considerable degree of construction field experience. Obviously a designer with all these qualities would be hard to find and as a consequence designers normally stick to a waterproofing system that they have used

in the past with any success rather than conduct the research required to match the proper waterproofing system to the specific project design requirements. Designers are also reluctant, for liability purposes, to place themselves in the hands of a manufacture whose product they are unfamiliar with, regardless of the claims of the manufacturer or the number of positive references and projects provided.

I found these obstacles to improved designs and the use of new products true even within my own organization. Appendix A provides a case history of my own efforts to change the standard specifications of the Naval Facilities Engineering Command for Fluid-Applied Elastomeric Waterproofing for Earth Covered Concrete Arch Magazines. I was eventually successful in my efforts but the resistance that I encountered reflected an attitude of extreme caution and little enthusiasm for changes in this field of engineering.

Contractors also play a major role in waterproofing system failures as even the best designed waterproofing systems and products will fail if improperly installed due to faulty equipment, untrained workers, insufficient surface preparation, unsuitable application environments, improper cure periods, and unauthorized shortcuts to save money.

CHAPTER TWO
DEFINITION AND PURPOSE OF WATERPROOFING

Waterproofing is a relatively impervious membrane, coating, or sealer used in concealed locations to prevent water from entering or passing through either horizontal or vertical building materials. Waterproofing is designed to exclude water even when the water is under a hydrostatic head (5).

Waterproofing is often confused with clear water repellents and bituminous dampproofing. Clear water repellants are intended to reduce water penetration into building materials by capillary action. They are normally used on exterior wall surfaces above grade to prevent damage of horizontal concrete by water, sodium chloride or other ice melting chemicals. Some clear water repellent coatings may also prevent soiling and staining and are frequently used on limestone and concrete for that purpose. Clear water repellents will not prevent the passage of water under a hydrostatic head or from air pressure.

Bituminous dampproofing is a coating that is used to prevent building materials from absorbing moisture that may migrate further into the building structure. As with the clear water repellent, dampproofing is not intended to prevent water penetration of water under a hydrostatic pressure. Both interior and exterior dampproofing, like waterproofing is almost always concealed. Table 1 shows the types of surfaces on which waterproofing (WP), bituminous dampproofing (DP), and clear water repellents (CWRC) are used.

Table 1 - Waterproofing, Dampproofing, and Clear Water Repellent Coating Uses (6).

	WP	DP	CWRC
Exterior above grade			X
Interior face of exterior wall		X	
Foundation wall			
Hydrostatic head	X		
No hydrostatic head		X	
Basement wall			
Hydrostatic head	X		
No hydrostatic head		X	
Elevator pit	X		
Tunnel	X		

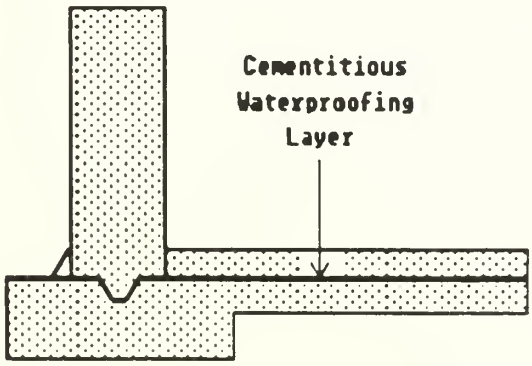
The term "waterproofing" in this report refers to materials used to waterproof below-grade walls, tunnels, pits and horizontal decks below the earth. With the exception of cementitious waterproofing systems the waterproofing systems discussed herein are not exposed to view and are therefore concealed. Most waterproofing membranes also inhibit water vapor transmission, which under certain circumstances can be detrimental. Trapped water vapor can blister some membranes or condense and freeze, damaging the membrane or the substrate. Cementitious waterproofing can be installed on either the interior or exterior side of the concrete substrate. All other waterproofing types discussed in this report must be installed on the same side as the water and be supported from the opposite side.

CHAPTER THREE
WATERPROOFING SYSTEMS

3.1 Waterproofing System Overview

There are three basic types of waterproofing systems: cementitious, membrane, and clay. Cementitious Systems are normally composed of plaster systems which are troweled on in two to four courses. The top course is a hard-finished plaster or a poured-in-place concrete topping to protect the lower courses from damage. Some systems are sprayed on similar to a "GUNITE" operation. Cementitious waterproofing on exterior surfaces are rarely covered with protection board or a drainage medium. Their uses in the past have been generally limited to horizontal applications such as traffic decks however, they are currently gaining wide acceptance in below grade foundation walls and slabs, swimming pools, utility and subway tunnels, pumping stations, aquariums, and nuclear power plants and mining. A typical Cementitious waterproofing application is shown in Figure 1.

Figure 1 - Cementitious Waterproofing of a Split Slab Concrete Foundation



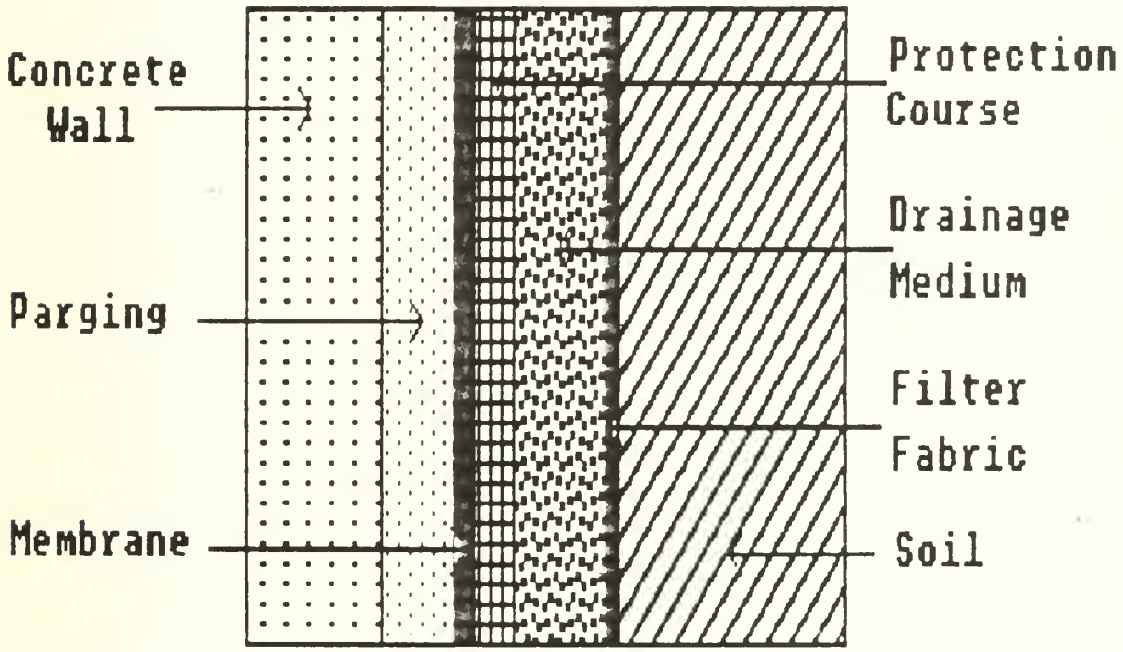
Membrane waterproofing systems are applied to either vertical or horizontal surfaces. Membrane systems consist of a membrane, a protection course, a drainage medium, and a layer of filter fabric. When the concrete surface does not have a uniform texture certain membrane materials will require a parging layer which is used to fill in pin holes or voids. This parging layer ensure that the membrane has a uniform surface for complete bonding. The protection course may be protection board or insulation.

The drainage medium may be either a gravel or sand bed, a pervious board, or a three dimensional sheet. Unless the filter fabric is a component of the drainage medium, a separate layer of filter fabric is needed over the drainage medium to keep fine soils from out which will eventually cause the drainage system to become clogged. Sometimes, the insulation in a waterproofing system is placed beneath the membrane. In this case special considerations must be given to prevent condensation from forming in the system, and a separate protection board is necessary. Figure 2 shows a typical vertical membrane waterproofing system (7).

Natural clay waterproofing systems are becoming increasingly more popular as they utilize the natural waterproofing properties of clay soils such as bentonite. A typical bentonite waterproofing system consists of membrane sheets composed of bentonite applied over the exterior surface of the concrete substrate. A drainage medium is not often used with this system however, where it is used a filter fabric is also required. A protection course is used

in vertical applications only when the backfill material contains sharp rocks. Protection boards are used more frequently when the bentonite is on a horizontal surface.

Figure 2 - Vertical Membrane Waterproofing System



A chart showing the general classification and evaluation of the various types of waterproofing systems is provided in Appendix B. Research material concerning waterproofing tends to be fragmented and specialized towards one type of system or another, Appendix B is the only document that I have encountered that considers all three of the major waterproofing systems (cementitious, membrane, and clay) and evaluates them based on product performance, application techniques, and general conditions. In researching waterproofing certain terms are often used

interchangeably by author's and manufactures. In Appendix B the Liquid Applied Solvent Systems and Preheated Liquid Applied Systems correspond respectively, to the Cold-Liquid Applied and Hot-Liquid Applied Membrane Systems referred to in this report. The Fully Adhered and Loose Laid Sheet Systems also fall into the category of membrane type systems.

3.2 Requirements Common to All Waterproofing Systems

Regardless of the waterproofing system chosen there are a number of requirements common to all applications. These requirements range from the preparation of the substrate to drainage and construction details. Some the more critical requirements are detailed in this section.

3.2.1 Compatibility

Every material used in each waterproofing system must be compatible with all other materials in the system or adjacent to the application. Items such as adhesives, primers, coatings, solvents, and substrate curing compounds must be evaluated to ensure that performance is not degraded as a result of unforeseen chemical reactions.

3.2.2 Substrates

The best substrate for waterproofing is a integrally sloped poured-in-place concrete slab. Masonry blocks and bricks are also commonly used for underground structures however, because of their greater number of joints they are not recommended for critical applications or no tolerance situations. Underground concrete structures should be designed to support loads without undue deflections, sloped

to drain, free of fins, pocket holes, and offsets which are detrimental to the waterproofing membrane. Care should be taken to ensure that the concrete finish specifications are consistent with the requirements of the Waterproofing membrane. Appendix A details an example where an urethane bitumen manufacturer, which was specified by contract, required that concrete surfaces be free of voids before application. Since the concrete finish specification only provided for a burlap rub, numerous pin holes and voids were present on the application surface. To resolve the problem a cement based coating (THOROSEAL) was installed over the concrete surface resulting in a contract adjustment of $425,000 and a 90 day time extension.

Most waterproofing systems require that surfaces be smooth, in plane, clean, dry, and free from dirt, dust, and other foreign substances. Concrete to receive waterproofing should be cured the number of days required by the manufacturer. In hot and/or humid environments certain volatile, liquid applied waterproofing materials when applied to even apparently dry concrete surfaces causes the "outgassing" of solvents and water vapor from the concrete. The effects of "outgassing" can be devastating to the membrane as the gases formed at the concrete/membrane interface eventually migrate to the exterior surface causing small pin holes and depressions in the membrane surface that significantly reduce the membrane's thickness and waterproof integrity. An example of this type of problem is provided in

Appendix A. Additionally, regardless of the waterproofing type chemical curing compounds should not be used.

Some manufactures of waterproofing materials require that their products not be installed over any material that was installed using a PVC or latex additive or coating while others do not have this restriction. Surfaces to receive bituminous or other liquid applied materials should be primed, unless not recommended by the manufacturer. Wood and other nailable substrates to receive waterproofing should be covered with an asphalt saturated organic fiber felt base sheet and nailed in place (8).

Another requirement common to all waterproofing materials is their ability to deal with water vapor from inside the structure. Concrete absorbs water and if the internal air pressure of the structure is great enough the water vapor will be driven though the wall to the exterior wall surface and Waterproofing system interface. Some waterproofing materials such as polymerized bitumen have the ability to allow the water vapor to escape through the waterproof layer to the surrounding soil while at the same time keeping liquid water from penetrating into the structure. This material property is similar to that found in "GORE-TEX" type materials. Other materials do not have this property and keep the water vapor from escaping. One of the leading causes of membrane failure is associated with the delamination between the membrane and concrete surface due to water vapor. To prevent delamination the concrete mix should be as impervious as possible by reducing the volume

of air voids in the concrete. This can be accomplished by avoidance of excessively wet concrete mixes, incomplete curing, and trapping air in the concrete during mixing and placing. The use of a uniform aggregate gradation and low water absorption by the mix aggregates will also improve the concrete's ability to resist water flow (9). As a general rule the higher strength concrete mixes are more impermeable than the lower strength mixes (10).

3.2.3 Drainage

Waterproofing systems work better and last longer when adequate drainage is provided to lower the surrounding hydrostatic head. Most waterproofing materials eventually disintegrate when water is constantly present. Emulsified (water soluble) asphalt compounds are particularly susceptible (11). Drainage is usually accomplished by placing a layer of pervious material between the waterproofing and the water. This layer often covers the entire surface of the underground structure and terminates in a water collection system such as a french drain or a perforated pipe embedded in a gravel bed. These systems act as vertical chimneys that funnel water away from the side of the structure and reduce the hydrostatic head on the waterproofing system. Horizontal surfaces are sloped to these same chimneys.

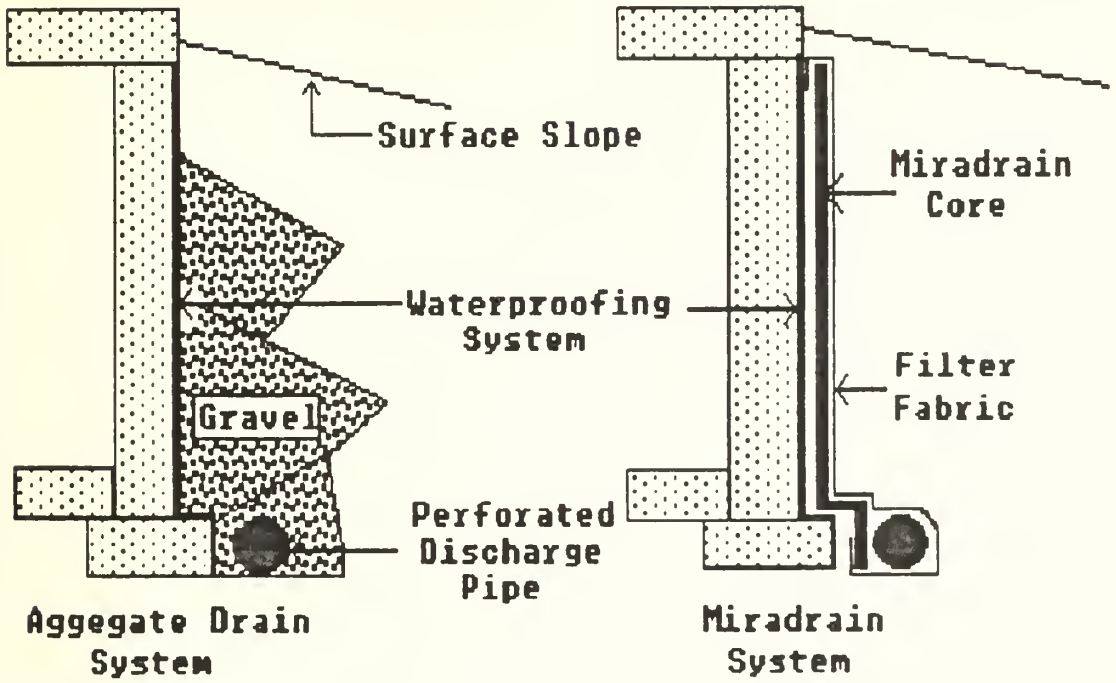
The traditional drainage materials have been gravel or sand because of their relatively low material cost and availability. However, these materials have not been without their disadvantages. Because of the volume of gravel or sand

required to provide adequate flow and the shear weight of the material, the use of construction equipment (such as a front end loader) is necessary to place the material along side and on top of the underground structure during construction. During this process the waterproofing system, even with a protection board installed, is often subject to damage due to the penetration of gravel, sand, or equipment into the waterproofing layer. Normally leaks remain undetected until after the structure is covered with earth and at this point the cost of repairing or replacing the damaged area becomes extremely expensive for the contractor. Realizing these shortfalls manufactures have developed prefabricated drainage boards and pervious sheet materials that have lower material and installation costs, require less construction equipment to install, have better drainage characteristics, are easier to repair and are constructed in a shorter period of time. My research and experience in prefabricated drainage structures concludes that there are many such products on the market today and their use has gained wide support in the construction industry. There are two such products that were used in the Kingsbay Naval Submarine Base Missile Production Facility construction that proved to be extremely effective drainage products, these systems are the MIRADRAIN 6000 prefabricated drainage structure and the Owens Corning Warm-N-Dri drainage board.

The Miradrain drainage structure consists of a light weight, 3-dimensional, high impact polymeric core and a filter fabric. The filter fabric is bonded to the dimples of

the polymeric core to maintain a rigid surface. This bonding prevents the backfill from pushing the fabric into the flow channels and reducing water flow. The filter fabric allows water to pass freely into the molded drain core where gravity draws the water through the flow channels to the discharge system. The filter fabric also prevents the adjacent soil from clogging the interior core structure and reducing it's flow characteristics. The MIRADRAIN drainage structure comes in rolls or sheets and is installed by using metal stick clips attached to the concrete and waterproofing system. The drainage panels are designed in such a way as to allow overlapping and interlocking by peeling back a portion of the fabric. The bottom of the drainage structure is wrapped around a perforated discharge pipe which can also be embedded in gravel. Flows in these panels vary from 5-15 GPM/FT width, weigh 4 OZs per square yard, are less than 3/4 inch thick and have a compressive strength of between 4,320 and 10,800 PSF. The system is usually installed by unskilled labor thus releasing tradesmen and equipment for other tasks. A diagram showing the differences between the traditional aggregate drain system and the MIRADRAIN system is provided in Figure 3 (12).

Figure 3 - Aggregate Drain System and Miradrain System



The Owens Corning WARM-N-DRY drainage board is similar to the MIRADRAIN system however the drainage board is a solid piece of rigid fiberglass and is fully adhered to the waterproofing membrane. The WARM-N-DRY Board is used exclusively with the Owens-Corning TUFF-N-DRY waterproofing system which acts as a total waterproofing system. The drainage boards comes in 4 by 4 and 8 by 4 foot sections which are bonded to the polymerized bitumen membrane immediately after it's application to the substrate. The drainage boards are primarily used in vertical applications, has a flow of 4-5 GPM/FT width, weighs 15 OZs per square yard, ranges in thickness between 3/4 - 2 3/8 inches, and has a compressive strength of up to 2000 PSF. The WARM-N-DRY board has the added benefit of providing thermal resistance

with R values of R3.1 for 3/4 inch board and R10 for 2 3/8 inch board (13).

3.2.4 Insulation

In most waterproofing systems where insulation is required the insulation is placed on the weather side of the waterproofing layer to protect the waterproofing layer and to lessen the chances of condensation forming underneath the waterproofing. Extruded polystyrene is the most popular type of insulation material and can be designed to have the same compressive strength as a wooden 2 by 4 (i.e. 600 psi).

Insulation is sometimes placed underneath the waterproofing layer. When it is, special consideration should be given to preventing condensation. In addition, placing insulation underneath the waterproofing limits the usability and negates the advantageous features of some waterproofing types. One major advantage of the fully adhered membrane waterproofing systems is that they make finding leaks easier. Water cannot migrate between the fully adhered membrane and the substrate, if insulation is placed directly against the concrete substrate this advantage is negated. Whenever insulation is needed in a system compatibility is critical. Both the insulation and waterproofing manufactures should be consulted about the type and placement of insulation within the waterproofing system.

3.2.5 Nailers and Cant Strips

Some, but not all, waterproofing systems require nailers to secure parts of the system in place. Where

nailers are required, they should be pressure-preservative-treated wood members set with their faces flush with the substrate. Cant strips should be installed at changes in direction in bituminous waterproofing systems, in liquid-applied waterproofing, and in other waterproofing systems where recommended by the manufacturer.

3.2.6 Protection Course

Waterproofing subject to damage during backfilling operations or damage from workers who may have to walk over the system to install it should be protected by rigid insulation board or protection boards. Protection boards are asphalt-core composition or fiberboard. Composition protection boards are semirigid sheets composed of asphalt-saturated felt layers. Thicknesses vary from 1/8 inch to 1/2 inch. Normally, the 1/8 inch board is used in vertical applications and 1/4 inch board in horizontal applications. In special cases were heavy foot or equipment traffic is expected a 1/4 inch board should be used. Fiberboard protection board is treated, asphalt saturated and coated organic fiberboard. Thickness is usually 1/2 inch. Fiberboard is not usually recommended to protect horizontal waterproofing systems. Protection boards should be positively fastened to the waterproofing system as recommend by the manufacturers. As shown in Figure 2 the Protection Course is normally placed right over the Waterproofing layer. In Hot-Liquid Applied Membrane systems the protection course is applied with the top coating before the other coats cure. In Cold-Liquid Applied Membrane systems the

protection board is applied to the dried and cured membrane using mastic compounds compatible with both the waterproofing system and the protection board.

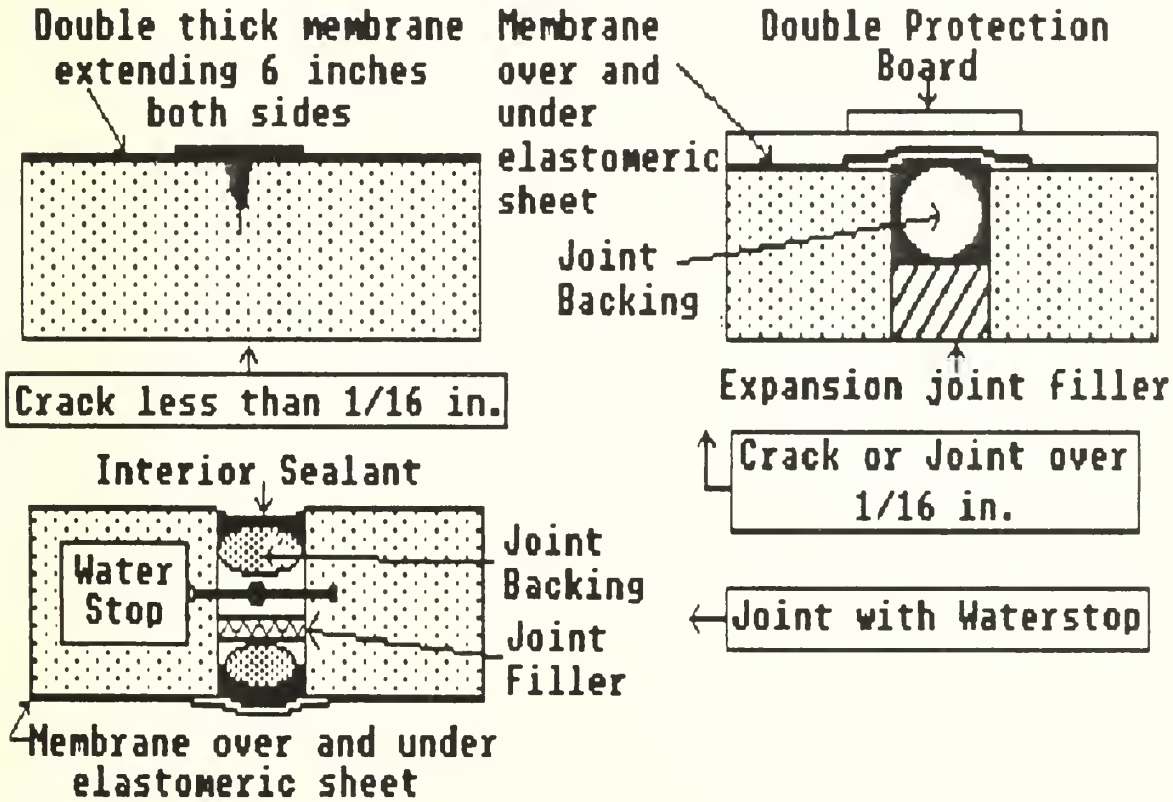
3.2.7 Joints, Cracks and Waterstops

> The joint is almost universally the weakest link in any combination of parts...(14).

Expansion joints should be installed in the concrete substrate to account for thermal, seismic, and settlement movements. Where joints occur, they should be accommodated in the waterproofing system. Each manufacturer normally has it's own procedure for bridging concrete joints and cracks in the concrete surface. Since waterproofing systems are most subject to failure at joints in the structure, especially when hydrostatic heads are present, waterstops in the substrate joint are often recommended. However, some structural engineers believe that these waterstops often are the cause of water penetration because they are so often deformed during concrete placement. Nevertheless, some form of expansion control must be imposed at the joints if leaks are to be prevented. Cracks in the concrete surface are also a prevalent source of leaks in waterproofing systems. Whether using cementitious, membrane, or natural clay waterproofing systems their ability to bridge existing and future cracks is limited. Therefore, before applying a waterproofing system to a concrete surface it must be carefully inspected for cracks larger than 1/16 inch. Normally, cracks under 1/16 inch are treated with a double thickness of the waterproofing layer being used over the crack extending 6 inches on either side of the crack. For

cracks in excess of 1/16 inch the crack is normally required to be routed out and caulked with an expansion joint filler. A joint backing is then inserted into the crack which is then coated with the waterproofing material. To give the joint added strength an elastomeric sheet is centered over the joint and covered with another layer of waterproofing material. Waterproofing layer thickness over the crack vary with each manufacturer but 60 mil for the first and 45 mil for the second layer are considered normal. Figure 4 provides typical joint, crack, and waterstop details for concrete surfaces (15).

Figure 4 - Typical Joint, Crack, and Waterstop Details for Concrete Surfaces



3.2.8 Flashings

Flashings are waterproofing products which are placed at corners, joints, and openings where water is most likely to penetrate the structure. Membrane type waterproofing systems sometimes extend at the edges, openings, and other projections to act as their own flashing. Rubber or plastic flashings are usually used in Liquid-Applied Waterproofing systems and other systems when specifically authorizes by the manufacturer. In most cases manufacturers will specify that flashings be coated with protective products to prevent damage from weathering and ultraviolet radiation. Natural clays are for the most part self flashing. Joints and edges are sealed using clays such as bentonite. Cementitious waterproofing systems are flashed in the same manner as any other cementitious material. Cementitious Waterproofing is brought up to within 1/4 inch of abutting surfaces and the joints are filled with sealant.

3.2.9 Weather Conditions

Waterproofing installations are very weather sensitive and should never be applied during precipitation. Certain solvent based bituminous membranes become abnormally volatile during high temperatures and humidity which results in "outgassing". The product of outgassing is gas bubbles that migrate through the membrane and exit at the exterior surface. When the gas bubble exits it leaves a pin hole in the membrane or a dimple like depression which destroys the waterproofing integrity of the membrane. Cold temperatures just as moisture affect the waterproofing materials ability

to bond to the substrate. The operating range of waterproofing products to various weather conditions must be thoroughly known before any application.

Moisture on surfaces to receive waterproofing products is not always easy to detect or measure. Some Waterproofing products require that the concrete surface be completely free of moisture for proper bonding. Moisture meters are ideal for random non-destructive sampling of the concrete surface. Moisture meters operate on either the conductance or capacitance principle. The conductance type moisture meter is considered superior to the capacitance type in that it is generally more sensitive to surface moisture and is unaffected by surface roughness (16).

3.3 Desirable Characteristics of Waterproofing Materials

Appendix B provides a comprehensive listing of material characteristics that should be considered when evaluating waterproofing systems. The relative importance of each characteristic will depend on the specific application. A waterproofing material, even though of good quality, does not necessarily provide all the characteristics desired by the designer so that trade offs must be made based on the most likely combination of conditions to be encountered. The most common material characteristics listed in their general order of importance are: Longevity, Low Permeability, Breathability, Hydrostatic Pressure Resistance, Leak Localizing Capability, Elastic Properties, Crack Bridging Ability, Resealability, Low Shrinkage, Puncture Resistance, Resistance to Degradation by Water, Resistance to Chemicals,

Compatibility with other materials, Non-toxicity, and Applicability to Vertical and/or Horizontal Surfaces. Table 2 provides relative performances of waterproofing materials most commonly used in the construction industry.

Table 2-Relative Performance of Waterproofing Materials(17).

Performance Criterion	Material				
	Cementitious Coatings	Polymer Modified Asphalt	Urethane Elasto-mer	Rubber Asphalt Sheet	Bentonite Clay Types
Longevity	5	4	3	4	5
Crack-Bridging Ability	-2	5	3	4	5
Low-Temp. Flexibility	-2	5	3	4	0
Substrate Preparation	2	5	2	3	5
Curing Time of Coating	4	3	3	5	5
Need for Protection	5	2	3	4	3
General Effective-ness	3	5	4	5	5
Cost Installed	4	4	3	3	3

Key: -2 = Not Recommended
0 = Questionable
+2 = Poor
+3 = Fair
+4 = Good
+5 = Excellent

CHAPTER FOUR
CEMENTITIOUS WATERPROOFING SYSTEMS

4.1 Material

There are basically two forms of cementitious waterproofing, both of which are nondecorative. The first are plaster like products consisting of Portland cement, fine aggregate, and sometimes acrylic or other plastic admix. They are intended for trowel or spray application. These materials are used either on the exterior or the interior of the walls. Portland cement based cementitious waterproofing materials are available either with or without pulverized iron fillers. When iron is used (metallic oxide waterproofing), an oxidizing agent is included in the mix to make the iron rust quickly and expand to fill the pores in the plaster material (18).

The second form of cementitious waterproofing is hydraulic cement, which is a compound of cement and rapid-setting nonshrinking hydraulic materials. Hydraulic cements are used for many purposes which include sealing holes, cracks, and open joints. They can also be used to stop water which is actually flowing at the time of application. Such a problem was encountered at the Kingsbay Submarine Base Vertical Packaging Building when underground utility tunnel began to leak at random locations under a hydrostatic head of 20 feet. A special HEY'DI AMERICAN CORP. hydraulic cement was applied to the active leaks which instantly sealed the leaks and the utility tunnels have remained dry to date.

The major advantage of cementitious products are their ability to provide membranes with low permeability, good

breathability, good puncture resistance, long life, and good resistance to ordinary chemicals. Their major disadvantage however is their inability to bridge wall cracks that form after the system is installed (19). Cementitious waterproofing products should not be confused with cementitious paint which are widely used as decorative coatings and for dampproofing exposed exterior walls. These cementitious paints are not waterproofing products, they serve only to repel precipitation and have no ability to keep water under a hydrostatic head from going through the structure. These products are often marketed as waterproofing products whereas their correct classification is a water repellent coating.

At the Kingsbay Missile Magazine complex the contractor installing the Magazine waterproofing system was convinced by his supplier that a product named THOROSEAL would be an effective waterproofing membrane. After researching the product specifications it was clear that the THOROSEAL product was a cementitious paint as classified by the Army Corp of Engineer Federal Specification TT-P-0035 (20) and was therefore rejected as an alternative waterproofing system. However, this product was considered to be excellent for providing a smooth surface over the rough concrete substrate to which a liquid-applied membrane was later installed. Accordingly, the THOROSEAL product was approved for this use only.

Cementitious materials normally comes in the form of an inorganic cement based powder which when mixed with water

and a bonding agent to a thick slurry consistency has a high degree of adhesion and penetration. For bonding to be effective it must be applied to a damp/wet concrete surface. The deep penetration action of the bonding is achieved by crystallization in the lower depths. This is caused by the alkali silicates containing in the cementitious material. The Alkali silicates, channelled by moisture, penetrate into the smallest pores and capillaries. There they combine with water and with free calcium particles, congeal and form highly insoluble calcium silicate crystals. Thus the lower penetration levels turn into an integral part of the waterproofing system. Since no sodium or chloride are added by the cementitious product it will not contribute to the corrosion of steel within the concrete (21).

Two of the leading manufacturers of cementitious waterproofing products are HEY'DI AMERICAN CORP. and VANDEX CORP. Although their products have slightly different compositions their product test properties are effectively the same. Table 3 provides test properties for both the HEY'DI cementitious waterproofing and hydraulic cement products.

Table 3 - HEY'DI Cementitious Product Test Properties(22).

Property	Test Method	Cure Time	Test Results (AVG.)
HEY'DI Cementitious Waterproofing Product K-11			
Adhesion	ASTM E-149	28 days	124 psi on Concrete
Tensile Strength	ASTM C-190	28 days	332 psi at 100% R.H.
Flexural Strength	ASTM C-580	7 days	472 psi
Permeability	ARMY COE CRD-C 48-55	7 days	2.6 E10-8 cm/sec (2 coats)
		7 days	1.7 E10-8 cm/sec (3 coats)
	Tested at Water Heads of 4.3 - 178 feet		
HEY'DI Hydraulic Cement Product Powder No. 1			
Adhesion	ASTM E-149	3 days	42.2 psi on Concrete
Tensile Strength	ASTM C-190	7 days	380 psi at 100% R.H.
Permeability	Army COE CDR-C 48-55	3 days	Range:8.1 E10-10 cm/sec to 7.6 E10-11 cm/sec
	Tested at Water Heads of 4.3 - 177 feet		

4.2 Application

Cementitious waterproofing products have been applied to a variety of large and small below grade projects which include the Atlanta Marta and Washington D.C. Metro subways, Los Angeles Sewage Plant, Laguna Beach Interceptor Pumping Stations, The Eisenhower Tunnel in Colorado, Phipps Bend Nuclear Power Plant in Tennessee, as well as basements, swimming pools, elevator pits, aquariums, and mines.

The cementitious waterproofer is best applied after the concrete substrate has cured for 7 days, although some products will allow application as soon as the forms are

removed. The major concern here is that the concrete should be allowed to develop shrinkage cracks before the application of the cementitious waterproofer. As stated earlier cementitious waterproofers do not have the ability to bridge cracks that develop after application of the coating. The concrete surface should be clean and damp to the touch with no standing or running water.

For standard applications the cementitious slurry is applied to the concrete surface using a cement brush in 2 to 3 coats, depending on the water pressure anticipated. The cementitious waterproofer is applied at the rate of 2.25 lbs. per square yard per coat. A standard application is a minimum of 4.5 lbs. per square yard for 2 coats unless otherwise specified (23).

For Spray applications a conventional spray machine suitable for cementitious materials with air pressure between 45 and 65 psi should be used. The first coat should be applied at a rate of 3.5 lbs. per square yard using a 8mm nozzle at a distance of 2 feet from the surface. Then the sprayed area should be brushed with a stiff broom to ensure the coating is even and no areas are left void. After the first coat reaches it's initial set mist the surface with water and apply the second spray coat at a rate of 1 lb. per square yard using a 4mm nozzle.

4.3 General Conditions

Cementitious waterproofing products should not be applied in temperatures below 40 degrees F. and once applied protected from temperatures below this limit. Only clean potable water should be used for mixing and surface preparation. The treated area should remain undisturbed and free from backfill material for 48 hours after application. If the surface of the waterproofed area is to be painted, lime based paints should not be used. The average cost of cementitious materials is approximately $0.45 per square foot, with labor, equipment and overhead a price of between $1.00-$1.10 per square foot is considered reasonable. Warranty problems become more difficult to enforce if the material and application is warranted separately which is normally the case. Most disputes arise over determining Whether the material was defective or whether the installer failed to apply the product properly. In any case the burden of proof is usually left with the owner of the structure. If at all possible and even at additional cost, the owner should insist on an application wherein the material and installation are warranted by one organization in the event of failure. As long as there is no major structural failure of the structure the owner should be adequately protected from bearing the cost of remedial repair work.

CHAPTER FIVE
MEMBRANE WATERPROOFING SYSTEMS

5.1 General

Membrane waterproofing systems include Cold-Liquid Applied Membranes, Hot-Liquid Applied Membranes, Fully Adhered Sheets, and Loose Laid Sheets. Cold-Liquid Applied Membranes are usually composed of either asphalt, tar, plastics, rubber, polymers, and urethanes or combinations thereof which are sprayed or mopped, at ambient temperatures, to form a continuous membrane over the concrete surface. The Hot-Liquid Applied Membranes are normally composed of hot rubberized asphalts or asphalt/coal tars which are preheated and also sprayed or mopped to form a continuous membrane over the concrete surface. Fully Adhered Sheet Membranes are composed of numerous rubberized, thermoplastics, and asphalt material combinations which come in sheet form and are adhered to the concrete surface in an overlapping pattern. The Loose Laid Sheet Membranes are similar to the Fully Adhered Sheet Membranes except they are not bonded to the concrete surface and the sheet are seamed together to form a continuous membrane.

5.2 Cold-Liquid Applied Membranes

Cold-Liquid Applied Membranes are high quality waterproofings used in non-traffic areas where visual esthetics are not important. The Cold-Liquid Applied Membrane market which has been dominated until just recently by one and two part asphalt modified urethane products have been replaced by a new generation of polymerized and rubberized asphalt or coal tar products. This change in

waterproofing preference stems from a number of disadvantages related to asphalt or coal tar modified urethane products. These disadvantages include low resealability, humidity sensitivity, toxicity of solvents, concrete cure time requirements, and flammability.

5.2.1 Material

As explained in Appendix A, the disadvantages of the asphalt modified urethane product forced the Navy to change it's Missile Magazine waterproofing specifications from a two part asphalt modified urethane product to a polymerized asphalt product. The major disadvantage of the urethane product was its acute sensitivity to humidity and moisture in an environment that was comparable to a swamp. This sensitivity to humidity required the concrete surfaces to be 100% dry, which was very difficult to achieve in the summer period along the South East Georgia coast. In addition, the high temperatures of the summer months caused the solvents to vaporize rapidly upon striking the hot concrete surface. This condition caused "out gassing" of the solvent and as the gases migrated to the surface of the membrane pin holes developed which greatly effected the waterproofing integrity of the system. The temporary solution was to double the coating thickness, through multiple coatings, at a significant increase in construction costs. The permanent solution was to find an alternative waterproofing product that did not exhibit these disadvantages for future magazine construction.

The Navy's research concluded that the polymer modified waterproofing products were superior to the urethane modified waterproofing products as evidenced in Appendix B which assigns an overall score of 131 to the urethane asphalt and 156 to the polymerized asphalt. Rubberized asphalts were also considered superior to the urethane asphalt products. The highest quality Cold-Liquid Applied membranes are therefore found in the high grade polymeric asphalts. They have the further advantage of not having to be mixed at the job site and do not present the environmental hazards of the urethane and coal/tar products.

Polymerized asphalts offer other advantages that the construction industry has sought in their waterproofing products. Their insensitivity to humidity and high ambient temperatures reduces the occurrence of "outgassing". Since polymerized bitumen is nonreactive to moisture the product can be applied directly after form removal with minimal surface preparation which is a distinct advantage to meeting tight construction schedules.

Polymerized asphalts provide excellent adhesion and eliminates horizontal migration of water under the membrane. Thus, if the membrane is punctured leaks can be more rapidly located and inexpensively repaired. The high elongation capacity permits the membrane to stretch in excess of 800%. It's low modulus of elasticity means that stretching puts minimal stress on the adhesive bond to the substrate. The polymer composition of the material allows water vapor to escape through the membrane while it provides superior

resistance to exterior water. This advantage reduces the chances of the membrane becoming delaminated at the concrete surface interface. The high elastic recovery of the material allows the membrane to return to it's original shape. With out this ability the membrane would thin out in critical areas and become subject to attack by water and structural damage. Polymerized asphalts have excellent resistance to degradation in soils and are very resistant to acids, salts, bases, mold growth, and bacterial attack (24). Table 4 summarizes some of the key material performance characteristics of polymerized asphalts based on a TREMPROOF 60 product.

Table 4 - Polymerized Asphalt Membrane Performance Characteristics (25).

Characteristic	Value	Test Method
Elongation	650%	ASTM D 412-68
Tensile Strength	250 psi	ASTM D 413-68
Strength @ 100% modulus	50 psi	ASTM D 413-68
Recovery from 350% elongation	90 to 95%	ASTM D 413-68
Tear resistance	40 psi	ASTM D 624-73
Water vapor permeability	0.14 g*gm/m*2/ mm Hg	Honeywell
Peel adhesion	15 lb/in.of width	TT-S002227E
Ultraviolet resistance	Good	
Curing time	Rubbery overnight @ 50% R.H.	

As stated in Appendix A the Navy choose to use the TUFF-N-DRY polymerized asphalt waterproofing system for the remaining Missile Magazines after the bitumen modified urethane membrane proved to be unsatisfactory. This system, manufactured by Owens Corning, was considered the best polymerized asphalt product evaluated for the advantages

described above and because of it's unique drainage system, Warranty provisions, reasonable costs, and certified applicator requirements. The TUFF-N-DRY waterproofing membrane is installed along with the WARM-N-DRY drainage board and is considered a completely compatible waterproofing system. The system can be installed from the lowest elevation to the above grade elevation in sections. This allows the installation to stop and go along with weather conditions and the earth backfill can be used as a platform for the next waterproofing section as construction proceeds up from the bottom of the underground structure. The installation must be constructed by a certified factory trained work force and the Warranty covers both material and installation. The material cost of the system was approximately 22% more expensive than the originally specified asphalt modified urethane system, but because of the savings in labor and time of installation the TUFF-N-DRY system's total construction cost ending up costing 16% less than the urethane system.

Coal Tar Polymerized materials have most of the advantages of the Asphalt Polymerized materials however, the coal tars can not be used where environmental considerations are paramount

Rubberized asphalts are composed of polymeric rubber, asphalt, and solvent. These products should not be confused with Hot-Liquid Applied Membranes which are also mainly composed of rubber. Rubberized asphalt membranes do not have as much elastic recovery as the asphalt polymerized

membranes and they cure by solvent evaporation which is a cause of "outgassing" and pin holes in the membrane. However, rubberized asphalts do offer such advantages as lower material costs, are well suited for interior uses if adequately ventilated, they have long storage lifes and do not require job site mixing. They also share similar chemical resistance and high elongation properties with the polymerized asphalt membranes. Rubberized asphalts are normally used in special applications such as roofs.

5.2.2 Application

Cold-Liquid Applied waterproofing membranes do not have the problems associated with built up or sheet applied membranes. There application by brush or spray is relatively trouble free. Liquid applied membranes eliminate seams and cut outs around projections thus minimizing potential leak points (26). Cold-Liquid Applied membranes must be applied in layers to achieve the specified membrane thickness. Vertical surfaces present the most difficulty in this regard because of the tendency of the membrane to sag due to gravity and cause thin and thick sections within the membrane. This can be avoided by applying the membrane in three to five layers depending on the ambient temperature, skill of the applicator, and good quality control procedures and inspections. The industry standard for membrane thickness is 60 mils however, every application must be evaluated by the designer and manufacturer to determine the degree of waterproofing required to meet the conditions of the site and any other external factors.

After application of the membrane and before the installation of the drainage medium or backfilling, the membrane should be tested for leaks. This can by accomplished by applying water to the membrane surface using a standard sprinkler system or if possible, water should be contained in the excavation to totally submerged the structure. The interior of the structure should be carefully inspected for leaks and repairs made as required. Water testing should be for a minimum of 24 hours and 3 days is preferred. Contract specifications should include provisions for testing before and after backfilling. After backfilling the entire waterproofing and drainage system should be tested for proper operation while the specialized installers are still on site to effect repairs if required.

5.3 Hot-Liquid Applied Membranes

Bituminous have been used for waterproofing since Biblical times. Prior to the 1960's the waterproofing market was almost completely dominated by built up systems, which consisted of multiple plies of asphalt or pitch and felt. However, since the there have been a great proliferation in both number and type of systems to reach the market place. There were several reasons for this change. The top reason was the high failure rate of the built up systems. One survey has indicated that as many as 20 to 30% of built up roofs fail in the first few years (27). Labor costs are another reason in that built up systems are highly labor intensive and the cost of labor is continually increasing. Also, the cost of felts and certain grades of asphalt have

risen exponentially and their availability has been increasingly scarce. The poor performance of built up systems is further substantiated by Appendix B. The built up system waterproofing system (Item III.B) received a score of 123 which is the poorest rating for the waterproofing systems evaluated.

These factors created a strong market for products combining better performance with simpler and less costly application methods, even at the expense of higher material costs. In Canada, where the severe climate (for example, Montreal: summer 90 degrees F, winter -30 degrees F) accentuates the performance deficiencies of the built up systems, the hot applied rubberized membrane (R/A membrane) was developed and has been successful in meeting the markets needs (28).

5.3.1 Materials

The first R/A membrane was developed by the Chemical Division of Uniroyal Ltd., in Canada, and was introduced to the waterproofing market in 1963. During more than 10 years of field experience, in critical areas, the failure rate was less than 1%, and those that occurred can be related to inexperience in the earlier years. In Canada R/A membrane waterproofing systems are standard practice. Adoption of this system in the United States is progressing along with a growth in diversity of applications.

The rubberized asphalt based waterproofing membranes features many worthwhile characteristics including: flexibility at very low temperatures, speed of application,

immediately functional, no storage problems, few weather restrictions for the application, accommodation to rough substrates, excellent bonding to substrate, self sealing, and relatively good elasticity and adhesion characteristics.

A typical R/A membrane is formulated from asphalts, oils, fillers, natural or synthetic rubbers, thermoplastic resins, and antioxidants. The asphalt content contributes to the thermoplastic, hydrophobic, and adhesive properties of the system. Oils act as plasticizers for the asphalt and rubber and improve the low temperature susceptibility. The fillers impart good load bearing properties and help control flow in the system. Rubbers are the key to improving temperature susceptibility of the asphalt which essentially raises the softening point and lowers the brittle point and provides the membrane with the required elastomeric properties of elongation and recovery. Thermoplastic resins are used in small quantities to control flow at slightly elevated temperatures. Antioxidants are added to protect the membrane from ultraviolet radiation while exposed (29). Table 5 provides the performance characteristics of rubberized asphalt.

Table 5 - Rubberized Asphalt Membrane Performance Characteristics (30).

Properties	Performance Characteristics
Low Temperature Flexibility	0 to -25 deg F
Low Temperature Elongation	0 to -40 deg F(1/8in. elong.)
Elasticity	5 to 70% recovery @ elong.
Flow	0 to 0.5 cm
Softening Point	170 to 200 deg F
Toughness	5 to 30 in*lb
Adhesion	Cohesion failure @ room temperature at a 45 deg angle
Permeability	0.01 to 0.03 Perms
Viscosity	5000-50,000cP @ 350-450 deg F
Chemical Resistance	Good to Excellent
Water Absorption	0.3 to 1.0% max
Oxidation Resistance	Good to Excellent

5.3.2 Application

The high performance R/A membranes contain rubber of various types in different cured states and forms. The presence of rubber makes it necessary to use an indirect heat melter (double jacket) with positive agitation. This equipment ensures a uniform transfer of heat to the R/A and avoids damage to the heat-degradable rubber phase due to localized over-heating. Mobile melters are available from 150 to 5000 lb. As temperatures are very important melters are equipped with two temperature gages; one for the heat transfer oil (100 to 700 deg F) and one for the R/A (100 to 500 deg F). Other equipment required are propane torches for drying wet concrete surfaces, large heavy brushes and vacuum unit or an air compressor to clean the surface, a spray unit for the primer, pails to carry the hot R/A, and squeegees to spread it.

Before application the concrete surfaces should be free of defects or foreign matter which will interfere with adhesion. Items such as excess laitance, scaling, frozen concrete, certain types of curing compounds, dirt, oil, and grease should be removed just prior to priming the surface.

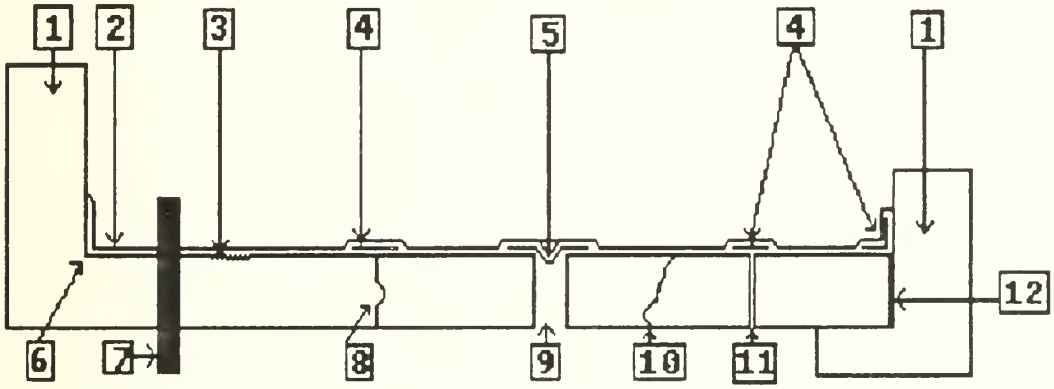
The adhesive properties of R/A membranes are such that they will bond directly to the concrete surface however, primers are used as an added safety factor. Primers are normally asphalt cutbacks but asphalt emulsions are becoming more popular for applications where low ambient temperatures are not expected.

Application is relatively fast and straight forward. The hot R/A material, at the recommended temperature, is transported from the melter to the application area in 5 gallon pails and poured directly on the concrete surface where it is spread using a squeegee. Pumping equipment has been evaluated but because of the high viscosity, thermoplastic consistency, and rubbery nature of the R/A material many problems remain to be solved.

When R/A is applied to a concrete surface it conforms to all surface irregularities, around columns and pipes, or other protrusions. Cooling normally takes 5 to 10 minutes and within a few minutes after application water cannot get through or under the membrane which is a major advantage in getting the job completed in freezing weather or when rain is imminent. Cracks up to 1/16 inch formed in the concrete substrates after the membrane has been applied will be bridged. Normal applications of R/A membranes are 3/16 inch

(187 mil) which are applied at 1 lb per square foot. Figure 5 provides details of a R/A membrane over poured concrete.

Figure 5 - Details of an R/A Membrane Over Poured Concrete (31).



1. Concrete
2. R/A Membrane
3. Rough Concrete
4. Cured Rubber Sheet
5. Reinforced Cured Rubber Sheet
6. Monolithic Joint
7. Pipe in Concrete
8. Construction Joint
9. Expansion Joint
10. Crack
11. Expansion Joint
12. Non-Monolithic Vertical Joint

5.4 Sheet Membranes

A wide variety of materials are available as prefabricated sheets and provide excellent resistance to chemicals and hydrostatic pressure as well as good resistance to punctures, freeze/thaw, shrinkage, degradation in water, and elasticity. Their disadvantages are primarily characterized by their inability to reseal cracks, breathability, and the waterproof integrity of the sheet seams. Materials include Rubberized Asphalt with

Polyethylene Cover, Vulcanized Rubbers such as EPDM, Butyl, and Neoprene, Thermoplastics such as PVC, CPE, HDPE, and Hypalon, Impregnated Asphalt Composites, and Thermoplastic/asphalt composites. The cost of sheet systems are generally higher than other types of waterproofing systems because of the higher labor costs associated with it's installation. These additional costs stem from higher skill level requirements, vertical applications require larger crew sizes, production rates are somewhat lower, and transitions require additional material and work.

5.4.1 Material

Among the thermoplastic sheets the Polyvinyl Chloride (PVC) and Chlorinated Polyethylene (CPE) are the easiest to seal at the seams by solvent welding. However, PVC sheets tend to shrink excessively and become brittle with increasing age. The rubber sheets that are used most often in underground concrete structures are Butyl rubber and Ethylene Propylene Diene Monomer (EPDM). The adhesives with which they must be sealed are not quite as effective as the solvents used to seal plastic sheets. Butyl and EPDM are similar to one another in strength and elongation but EPDM is more resistant to acids, oils, and solvents. Neoprene sheets are superior to either Butyl or EPDM in strength but not in elongation as noted in Table 6. However, the Neoprene sheets are used less often because of their additional material cost (32).

Table 6 - Tensile Properties of Sheet Membranes (33)

	Tensile Properties					
	Ultimate Strength, psi			Elongation at Break, %		
Degree F	140	77	0	140	77	0
Neoprene	1580	2140	3170	>250	290	300
Butyl	1320	1460	2230	290	340	360
EPDM	1130	1470	2330	>300	400	340

5.4.2 Application

Their are two methods of application for waterproofing sheet membranes; fully adhered and loose laid. The fully adhered sheet membranes are the most commonly used as they very closely parallel the advantages of liquid applied membranes. The fully adhered sheet membranes are easy to set up for, are not humidity sensitive, require little cure time before becoming usable, has good quality control characteristics, does not require specialized equipment, is compatible with most other materials, is non-toxic, does not require complete curing of the concrete before application, and usually protection boards are not required.

The disadvantages of sheet membranes are normally a function of the substrate surface. Vertical applications, especially deep excavations, will require special application equipment to ensure full adhesion to the substrate. The concrete surface must also be completely clean and free of surface defects for proper bonding. Some vertical applications also require primers to ensure bonding of the sheet membrane to the substrate. The most popular sheet membrane in industry appears to be the self adhering rubberized asphalt sheets with polyethylene covers. These

membranes come with peel away covers which are removed just prior to application exposing the sheets adhesive which is then pressed onto the concrete surface. Other adhesive systems require that the adhesive be applied to either the substrate or sheet prior to bonding it to the concrete surface. After application some manufactures require that the sheets be rolled with a handheld roller which assures intimacy of contact and full adhesion.

Loose laid sheet membranes are not bonded to the substrate and therefore will bridge cracks more readily than the fully adhered sheet membranes. But because of this advantage the loose laid membrane will not reseal newly forming cracks and if a leak does occur, locating it will be more difficult as the water is free to migrate along the interface between the concrete surface and the sheet membrane. This system is usually used over large horizontal surfaces rather than vertical walls. The success of a loose laid sheet membrane is primarily dependent on the seaming method employed. Manufactures differ widely in this area some using solvents and others heat fusion. Seaming can take place in the field or at the factory. Which ever method is used quality control becomes critical to the waterproofing integrity of the system. Most designers and installers prefer as few seams as possible, however sheet widths are determined by the manufacturing process. To keep seaming to a minimum in the field, where ideal environmental and cleanliness conditions are more difficult to obtain, manufactures pre-seam larger width sheet membranes in the

factory where conditions, procedures, and quality can be more easily controlled.

The leading manufacturer of loose laid sheet membranes in the United States is GUNDLE who uses High Density Polyethylene (HDPE) as their waterproofing material. Their primary market is the Landfill and Mining Industry however, their membranes are becoming increasingly more popular in the waterproofing of underground facilities. GUNDLE uses a patented extrusion weld seaming method which combines heat, an extruded polymer material and mixing action to provide a homogeneous bond between membrane sheets. This seaming process has been remarkable successful in preventing seam failures and increasing the longevity of the membrane (34).

CHAPTER SIX
NATURAL CLAY WATERPROOFING SYSTEMS

Natural clay waterproofing systems received the highest overall evaluation rating as evidenced by Appendix B. The most prevalent type of clay used is Bentonite. Bentonite swells to 10 or 20 times its volume when exposed to water and shrinks to its original volume when dry. Used in sufficient quantities, it expands when water is present and blocks any adjacent channels through the wall, keeping the water out. It can adhere to rough surfaces at almost any temperature and can bridge cracks and reseal any punctures. It does not work well either in soils that are high in salts or in arid climates where sudden rainstorms can penetrate a foundation before the clay has time to swell. Bentonite is available in several forms such as a spray grade bentonite with polyethylene cover, Bentonite panels using cardboard, Bentonite mats using geotextiles, or Bentonite sheets using HDPE (35).

6.1 Material

Natural clay type waterproofing materials have many other excellent characteristics such as longevity, leak localizing capabilities, hydrostatic pressure resistance, are not temperature or humidity sensitive, compatibly with other material, non-toxic, and are nonflammable. Their cost are very competitive with the cementitious and membrane waterproofing systems. During construction at the Kingsbay Naval Submarine Base natural clay waterproofing materials were used extensively in underground tunnels, missile silos and pits, control rooms, and testing rooms under constant

hydraulic pressure. Without exception, no leakage occurred in these facilities as a result of a natural clay waterproofing membrane failure. The primary clay membrane used was a VOLCLAY SWELLTITE 1000 manufactured by the AMERICAN COLLOID COMPANY which is a composite of polyethylene adhered to a butyl rubber/ bentonite compound. This product is typical of most bentonite sheet membranes which is the most widely used form of natural clay membranes. It is self adhering with an adhesive surface on one side. Physical properties of this clay membrane are provided in Table 7.

Table 7 - Volclay Swelltite 1000 Physical Properties (36).

Property	Test Results	Test Method
Thickness	60 mil	ASTM D 217
Penetration 150 GTL	58	ASTM D 9379
Flash Point	465 deg F	
Color	Dark Gray-black	
Permeability	1 E-12 cm/sec	
Puncture Resistance	40 min	ASTM E 154
	250 min	ASTM D 781
Specific Gravity @ 77 deg F	1.57	ASTM D 71
Tensile Strength	260 min	ASTM D 412

6.2 Application

Natural clay waterproofing systems offer many application advantages such as easy set up, low skill level requirements, good quality control standards, requires no special equipment , has a relatively high production rate, and does not require extensive substrate preparation.

Natural clay membranes such as bentonite can be sprayed applied and covered with a protective layer or

applied in panels, mats, or sheets. The panels, mats, and sheets are overlapped by 2-3 inches and upon exposure to water are self sealing and therefore continuous. Bentonite is often applied to shoring and sheeting or against existing construction before new walls are placed, where access for application of membrane material is not available. The complete cure of concrete is not required before bentonite application, but some cure will prevent excess swelling. Bentonite can only bridge cracks up to 1/8 inch wide. Wider cracks must be filled.

Bentonite thickness should be doubled over joints in the substrate and at corners and intersections. Sometimes, bentonite strips are embedded in concrete joints as added insurance against water protection. Protection boards are sometimes recommended by the manufacturer depending on the type of excavation and backfill material. Bentonite panels, mats, and sheets are usually nailed in place or fastened using bitumen and should be rolled immediately after installation to insure a tight bond at overlapped seams and complete adhesion to the substrate. Other application requirements, such as priming agents to improve adhesion on concrete surfaces, may be recommended by the manufacturer depending on hydrostatic pressure, substrate materials, edge conditions, and a number of other factors (37).

CHAPTER SEVEN
WATERPROOFING PROBLEMS AND SOLUTIONS

7.1 General

Free water flowing through walls, wet or damp walls, peeling or blistering finishes, and spalling concrete or masonry suggests that the existing waterproofing is no longer preventing water from entering the underground structures or that the waterproofing system does not exist. However, before jumping to conclusions the possibility of condensation; leaks from materials above the top level of the waterproofing or adjacent to the waterproofing; plumbing or mechanical equipment leaks; and other failures may be responsible and should be investigated and eliminated as possible causes of the water leakage.

Most waterproofing failures are due to improper substrate or waterproofing system design or installation and often occur because of one of the following reasons:

- The substrate cracks, dislodges, or otherwise fails.
- Substrates were not properly prepared and cured or the required priming was omitted.
- The wrong waterproofing or flashing material was used.
- The waterproofing material was incorrectly installed.
- The wall was coated on both sides with impermeable materials, preventing moisture vapor from leaving the wall.
- Asphalt emulsion was not permitted to cure properly.
- Insufficient number of plies or material thickness was used to withstand the hydrostatic head present.
- Cants were not installed at the bottom of walls and other direction changes.
- Reinforcement was not installed for membrane waterproofing at corners and nonmoving joints in the substrate.
- Building movement from thermal changes, seismic, or settlement was not accommodated.
- Waterproofing edges and junctures between waterproofing and other materials were not properly

flashed or otherwise treated to exclude water.

- Penetration flashings were not properly designed or installed.
- Waterproofing or flashing were not extended above the water level at adjacent walls and curbs.
- Exterior wall waterproofing was not extended above the grade.
- The waterproofing was installed over incompatible materials.
- The waterproofing system contains incompatible materials.
- Reinforcements or flashings are incompatible with the waterproofing membrane.
- Protection course was not installed or improperly installed permitting the waterproofing to be damaged during subsequent construction operations.
- Joints between cementitious waterproofing and other materials and penetrations were not filled with sealant (38).

7.2 Repairing, Replacing and Extending Waterproofing

Even in the case where the waterproofing system has been installed correctly and does not leak, it may become necessary in the future to repair, replace or extend the system to meet unforeseen requirements and the natural deterioration of the materials.

7.2.1 Compatibility

Membrane, adhesives, solvents, bitumens, and other materials used to repair existing waterproofing must be compatible with the existing materials in every respect. The best way to ensure compatibility is to have the manufacturer of the new material inspect the existing waterproofing system and substrate, and conduct compatibility tests. If possible when repairing or for partial replacement use the same material as the existing. Even in this case compatibility tests are recommended as formulations may have changed or the material may have undergone unanticipated chemical changes.

7.2.2 Repairing Existing Waterproofing

Before deciding to repair existing waterproofing, get an expert's recommendations. Waterproofing repairs for underground structures are expensive and if the repair is not well thought out the repair will be ineffective. A major problem with repairing waterproofing is locating the leak. Even when it is possible to isolate a leak in horizontal waterproofing by flood testing, finding the actual leak requires tearing off the covering material. Often the process of tearing off the waterproofing can cause other secondary leaks. For this reason it is common to completely replace the waterproofing in the zone where the leak is.

7.2.3 Replacing Existing Waterproofing

Replacing waterproofing can in itself be expensive and dangerous. It is difficult to protect the exposed structure from sudden storms while the membrane is removed. However, there are clearly situations where replacement is the correct decision. When the decision is made the waterproofing system must be removed in its entirety including protection boards, drainage systems, insulation, and the waterproofing material down to the concrete substrate.

Before the new waterproofing system is installed the surface must be carefully prepared. The complete removal of the waterproofing membrane may leave the surface pitted with voids and rough which must be filled and leveled. Curing agents must be completely removed and the manufacturers instruction should be carefully followed in installing the

new system. The substrate may require a primer and reinforcement should be added to those areas recommended by the manufacturer. Where the new and old waterproofing systems meet there should be a substantial overlap or a complete separation and transition joint acceptable to the manufacturers.

7.2.4 Extending Existing Waterproofing

When waterproofed walls are extended, extension of the waterproofing will almost certainly be required. When an expansion joint is installed between the original wall and the extension, the joint must be compatible with both the existing and new waterproofing materials. The two waterproofing systems do not have to be of the same type. However, if they are different materials compatible is essential. If an expansion joint is not used then the systems should be overlapped and sealed in accordance with the manufactures recommendations.

7.2.5 Installing New Waterproofing Over Existing Materials

It is sometimes possible to install one type of waterproofing over another on an existing structure. For example a concrete substrate with a cementitious waterproofing system may have either a liquid applied membrane, sheet membrane or a natural clay material applied to it if the manufactures agree on the compatibility of the materials. In most cases where the existing substrates to be waterproofed are coated or painted, it is necessary to remove them before applying new waterproofing. Coatings and

paint should only be left in place when the new waterproofing manufacturer specifically approves.

When acceptable to the manufacturers it is sometimes possible to place a slip sheet or barrier between incompatible waterproofing materials. Slip sheets and barriers are not applicable when it is required that the new waterproofing material bond directly to the substrate. Liquid applied membranes should not be used on a concrete topping slab that covers a waterproofing membrane without the manufacturers specific approval. Such double applications can cause delamination or blistering of the new waterproofing.

7.3 Waterproofing Specifications

The specifications of waterproofing systems should be much more carefully considered than has been the practice of the past. It is also strongly recommended not to leave the selection of waterproofing systems up to the contractor as often is the case in performance type specifications. Because of the level of sophistication required, knowledge of the overall design requirements, and specific knowledge of waterproofing technology the designer should be responsible for the careful selection of the waterproofing system. The designer should work carefully with waterproofing manufacturers and obtain constructability input from contractors prior to making any final decision on the type of waterproofing system and components to be use.

It is highly recommended that the (13) Product Performance, (21) Application Techniques, and (6) General

Condition factors listed in Appendix B be carefully considered in reviewing and selecting the appropriate waterproofing system.

Once the waterproofing system has been selected the specifications should be written as closed as possible to substitute materials and products. The designer must therefore provide detailed description, workmanship, and quality specifications so that no misunderstanding of the designer's intent can be made. The use of "or equal" language is recommended only when proprietary specifications are not possible. If "or equal" specifications are used the designer must make sure that the specifications are sufficiently detailed to ensure compatibility between all components of the waterproofing system. In addition, when "or equal" language is allowed the designer must be given broad contractual authority to reject submittals that are considered unsuitable and do not meet the salient design features specified.

A general specification covering all waterproofing systems would not be practical because of the wide variety and combinations of waterproofing products currently available on the market. However, Table 8 provides a listing of important factors that should be considered whenever a waterproofing specification is required. These factors should also be closely coordinated with the manufacturers specifications and requirements.

Table 8 - Important Factors to Consider When Developing Waterproofing Specifications

1. Qualifications of the Applicator.

2. Submittals - Evidence of Applicator Qualifications, Manufacturer's Certificate of Conformance, Catalog and Application Data, and Samples.

3. Delivery and Storage of Materials.

4. Environmental Conditions.

5. Carefully review the Physical Performance, Application Techniques and General Condition requirements of Appendix B and ensure that product materials comply with these requirements, the structural design and other design criteria.

6. Membrane should be impermeable to water but allow water vapor to pass.

7. Membrane should provide a continuous film without areas of weakness and lend itself to the design details of the structure.

8. Materials selected must be compatible.

9. Ensure that surface to be treated has been prepared to provide a positive bond to minimize the lateral migration of water.

10. Application of the waterproofing products must be specified in accordance with the manufacturer's requirements.

11. The membrane selected should maintain it's physical properties, such as elasticity and durability, over a wide range of environmental conditions.

12. Quality control specifications should be reviewed to ensure that each phase is properly inspected and tested prior to proceeding with the next phase. Testing of the installed waterproofing system prior to and after backfilling, by the continuous application of water over extended periods of time, is essential and should be specified.

13. The waterproofing system should be guaranteed for both material and performance by the installing contractor. Manufacturers representatives should also be required by specification to be on site during the installation of their product.

CHAPTER EIGHT
CONCLUSION

In this paper, I have discussed several elements important to the successful specification and installation of waterproofing systems on underground concrete structures. These elements are interdependent. The structural concrete design, product selection, installation details, and quality of workmanship are of equal importance to the functioning of the installed system. As stated in the introduction the primary task of this paper is to provide some background for selecting a suitable waterproofing system for underground structures. However, system selection involves decisions based on judgement. If this were not so a simplified list of physical properties prepared by a materials expert could easily replace this paper. The relationship of properties is of major importance compared to any one specific property of the waterproofing material. It is therefore prudent that before a waterproofing system is selected manufactures and material experts, designers, and installers act as a team in the selection of an appropriate waterproofing system.

The bottom line to the selection of a waterproofing system is to provide the owner or occupant of an underground structure with a system that is leak free. Whether this goal will be realized is a function of those responsible for formulating, specifying, designing, and installing the waterproofing system. The final performance and success of the installation is ultimately dependent on the identification of those factors and requirements which lead to the selection of the proper waterproofing system. A

through understanding of product performance, application techniques and general conditions are therefore necessary to achieving the goal of a leak free underground structure.

The reason for waterproofing failures as discussed are varied and can be found in all phases of manufacturing, design, and installation. It is also evident that leaking underground structures are prevalent through out the construction industry. It is my conclusion that these trends will continue unless designers increase their knowledge of waterproofing systems and increase the involvement of manufactures and installers in the selection and specification of these systems.

It is my conclusion that there is no one best waterproofing system and that any of the waterproofing systems discussed herein has an appropriate application. The designer however, must select a waterproofing system based on his knowledge of the structural design, site conditions, costs, environment and other factors. To begin the selection process it is recommended that Appendix B be reviewed to identify the waterproofing type or types that most closely meets the designers needs. These waterproofing types should then be reviewed with manufacturers and installers for possible problems and solutions. The designer can then make his selection and modify the design to incorporate changes recommended by the manufacturers and installers.

Because of the general lack of practical expertise in waterproofing systems and having had some experience in this

field, I feel that it would be appropriate for this report to also reflect some of my personal recommendations concerning the selection of a waterproofing system for underground structures. In general, I believe Natural Clay (Bentonite sheets adhered to HDPE) to be the best all- round system due largely to its self sealing properties as described in Section 6.1. This is followed by Liquid-Applied Polymeric Asphalt Membranes such as the TUFF-N-DRI System explained in Section 5.2.1 and for highly stable structures, Cementitious type systems such as the HEYDI K-11 product detailed in Section 4.1. For underground structures over 25 foot deep the Natural Clays are particularly suitable. Prefabricated drainage structures such as WARM-N-DRI and MIRADRAIN must be carefully evaluated for compression and reduced flow characteristics beyond the 25 foot level. Because TUFF-N-DRI and WARM-N-DRI offers a complete waterproofing system it is highly recommended for standard residential, commercial, and industrial applications down to 25 foot and beyond, as long as the WARM-N-DRI drainage board flow properties are carefully considered.

After or during construction if problems appear with the selected waterproofing system both the manufacturer and installer must be involved to identify the problem and recommend solutions. Designers must ensure that the manufacturer's instructions are carefully followed by installers to prevent the occurrence of secondary problems.

Through the expanded knowledge and understanding of the reasons for waterproofing failures; the various

waterproofing types and uses; criteria for selection; typical waterproofing problems and solutions and team work between designers, manufacturers and installers the occurrence of leaking underground structures will be significantly reduced resulting in lower overall waterproofing costs and increased owner satisfaction.

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APPENDIX A

DEPARTMENT OF THE NAVY
OFFICER IN CHARGE OF CONSTRUCTION
NAVAL FACILITIES ENGINEERING COMMAND CONTRACTS, TRIDENT
293 POINT PETER ROAD
SAINT MARYS, GEORGIA 31558-0768

ROICC:TFB:mah
6856R
10 June 1988

From: Officer in Charge of Construction, Trident
To: Commander, Naval Facilities Engineering Command, Code 04

Subj: NAVFAC NFSS-M19, SECTION NO. 07120; FLUID-APPLIED ELASTOMERIC WATERPROOFING FOR EARTH-COVERED CONCRETE ARCH MAGAZINES; RECOMMENDATIONS CONCERNING

Encls: (1) Owens/Corning Fiberglass (OCF) "TUFF-N-DRI" Product Brochure
(2) OCF Manufacturer Section 07125 of August 1987
(3) OCF "TUFF-N-DRI" Installation Procedures of June 1986
(4) Dewberry & Davis ltr 17 of 15 May 1987
(5) SVERDRUP Corp. ltr 8220-87-3038 of 8 June 1987
(6) Concrete Solutions, Inc.'s ltr of 9 April 1987
(7) OCF ltr of 1 May 1987
(8) OCF Warranty of 1 May 1987
(9) C Construction Company ltr 71 of 1 June 1987
(10) OCF ltr of 23 July 1987
(11) OCF ltr of 18 August 1987
(12) VHS Video Tape of "TUFF-N-DRI" Installation

1. This letter provides product and procedure recommendations for your consideration in modifying NAVFAC Standard Specification-M19, Section No. 07120 for fluid-applied elastomeric waterproofing on earth covered concrete arch magazines. Construction of the first fifteen concrete arch magazines at the Naval Submarine Base, Kings Bay, Georgia presented a number of problems associated with the use of the NFSS-M19 specified bitumen modified urethane waterproofing. During the high temperature and humidity conditions of the summer, the spray applied urethane based bitumen produced excessive volatilization causing gases to form and escape (outgassing). To make the urethane waterproofing material fluid enough for spray application, a cut-back solution was required which increased the outgassing. The escaping gases created pin holes and depressions that significantly reduced the elastomeric mil thickness and waterproofing integrity. Government inspectors verified that all specification requirements and manufacturer's recommendations were rigidly enforced. To mitigate the effects of outgassing the contractor was required, by the product manufacturer and before the urethane bitumen could be applied, to obtain 0% surface moisture on the concrete magazine arch as read by an approved moisture meter. The 0% surface moisture conditions were impossible to achieve during the tropical summer conditions at Kings Bay, Georgia and construction delays were experienced. Additionally, the urethane bitumen manufacturer required that the concrete surface be free of any voids and a cement based coating (THOROSEAL) was applied to provide a completely smooth application surface. The use of Thoroseal and delay impacts eventually resulted in a contract adjustment of $425,000.00. Through intense Government inspection, waiting for the proper application conditions and additional spray coatings, the contract requirements were eventually met. The use of a prefabricated drainage structure, (MIRADRAIN 1000) in lieu of the specified 6" sand lens, was also approved and produced superior drainage characteristics.

2. Given the difficulty of using the urethane bitumen waterproofing product, numerous contacts were made with other Government agencies, your Mr. Colombus Key, Architect and Engineering firms, OICC Trident's Title 2 Contractor, and various manufacturers and suppliers. Through a rigorious evaluation process, a polymerized bitumen elastomeric waterproofing and prefabricated drainage board system was selected for use on the next forty-two (42) earth-covered concrete arch missile magazines. This system is manufactured by Owens/Corning Fiberglass under the product name of "TUFF-N-DRI" (elastomeric waterproofing product) and "WARM-N-DRI" (prefabricated drainage board). Although some difficulty was experienced adapting the drainage board to the curved magazine arches, the waterproofing system was totally successful. Enclosures (1) - (11) provide the pertinent product information used in evaluating the system.

3. In evaluating the "TUFF-N-DRI" and "WARM-N-DRI" waterproofing system, the following advantages were considered:

a. "TUFF-N-DRI" - Polymer-Modified Asphalt
Fluid-Applied Waterproofing Membrane

(1) Polymerized bitumen can be applied under high temperature and humidity conditions without the effects of outgassing. Polymerized bitumen is not reactive to moisture and can be applied shortly after removal of concrete forms. By contrast, urethanes require a 7-28 day concrete cure time prior to application.

(2) Lower millage thickness can be applied, with commensurate cost savings, without degrading the waterproofing integrity or reliability of the elastomeric membrane. For example, 60 mil is industry standard for polymerized products wherein NFSS-M19 requires a minimum of 100 mils for chloroprene modified asphalt and 85 mils for bitumen modified urethane waterproofing membranes.

(3) Adhesion and elongation properties are excellent. Elongation is 300% with "TUFF-N-DRI" versus 700% using bitumen modified urethane products. "TUFF-N-DRI" is hot applied and adhesion to concrete exceeds ASTM C836 requirements.

(4) The polymerized waterproofing membrane allows interior water vapor permanence and reduces the potential for membrane delamination along the bonding plane.

(5) Polymerized waterproofing membrane has excellent resistance to degradation in soils and is very resistant to acids, salts, bases, mold growth, and bacterial attack.

(6) After patching honeycombs and any large tie holes, "TUFF-N-DRI" can be applied. No surface priming is necessary. By contrast, urethanes require a primed, smooth surface, free of any pits or voids. Lack of attention to this detailing using urethanes can result in severe blistering.

b. "WARM-N-DRI" - Prefabricated protection, drainage and insulation board

(1) Ease of installation reduces construction time. Board is bonded to "TUFF-N-DRI" when still tacky and earthwork can proceed immediately.

(2) "WARM-N-DRI" provides a uniform drainage blanket. Drainage ability of between 850-1000 Darcies exceeds gravel at 200+ darcies and sand at 15-200 darcies.

(3) "WARM-N-DRI" acts as a protective barrier for elastomeric membrane to prevent damage during construction.

(4) "WARM-N-DRI" provides thermal resistance depending on thickness, between R2.5-10.0, which reduces HVAC loading within the magazines.

4. The Owens-Corning Fiberglass Corporation (OCF) sells their "TUFF-N-DRI" and "WARM-N-DRI" products as a complete waterproofing system and as such warrants both labor and material for (3) years. The waterproofing contractor must also be certified by OCF. This is a distinct advantage over other waterproofing material suppliers and contractors who only warrant either the labor or material. The customer is often confronted with determining the cause of any subsequent water leaks due to a failure of the waterproofing system. A complete waterproofing system approach eliminates the need for the Government to determine the cause of failure in the event of poor workmanship or a faulty product.

5. The below listed personnel may be contacted for more detailed information:

a. LCDR T. F. BIGGINS, P. E. 912-673-2673
ROICC
Naval Submarine Base
Kings Bay, Georgia 31547

b. Mr. Michael K. Sutton 404-956-1465
Owens-Corning Fiberglass Corporation
6650 Powers Ferry Road, Suite 200
Atlanta, Georgia 30339

c. Mr. John Daugherty, PH. D., P. E. 614-587-7709
Owens-Corning Fiberglass Corporation
Technical Center, P. O. Box 415
Granville, Ohio 43023

6. In summary, the subject waterproofing system has been installed on 30 missile motor magazines which have been subjected to almost a full year of weather conditions and no leaks have occurred. In one earth covered magazine, a structural crack of 1/8 inch was detected. To determine if the waterproofing system had been damaged, it was subjected to a seven day water flood test. At the end of the period, no leaks or water vapor were observed. The structural crack was then repaired. Based on the above information and demonstrated working experience, it is recommended that fluid applied polymerized bitumen elastomeric waterproofing and a compatible prefabricated drainage structure be added to NFSS-M19, Section No. 07120 for Earth-Covered Concrete Arch Magazines as a preferred fluid applied waterproofing product.

It is also recommended that the OCF "TUFF-N-DRI" and "WARM-N-DRI" waterproofing system be specifically listed as a suggested source. At this time, twelve additional missile motor magazines are under construction and the contractor has chosen to use the OCF waterproofing system. Should a site visit by your staff be desired to view the installation of the OCF waterproofing system arrangements can be made through LCDR Biggins of the ROICC.

A. K. RIFFEY

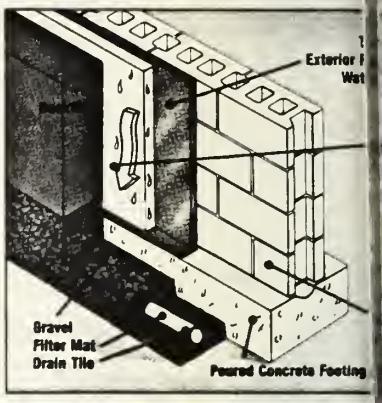
Tuff-N-Dri®
Exterior Foundation
Waterproofing System

Tuff-N-Dri

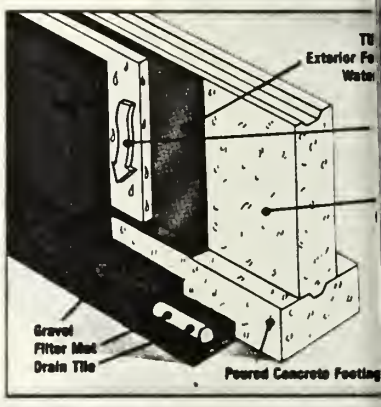
The Tuff-N-Dri® waterproofing system consists of two components: The Tuff-N-Dri waterproofing membrane and Warm-N-Dri® insulation, drainage and protection board.

Tuff-N-Dri membrane is a unique polymer-modified asphalt which provides a highly elastomeric, monolithic waterproof membrane when applied to concrete basements. The membrane is tougher and more resilient than materials commonly used on residential foundations. At the same time, Tuff-N-Dri is priced very competitively with other waterproofing products.

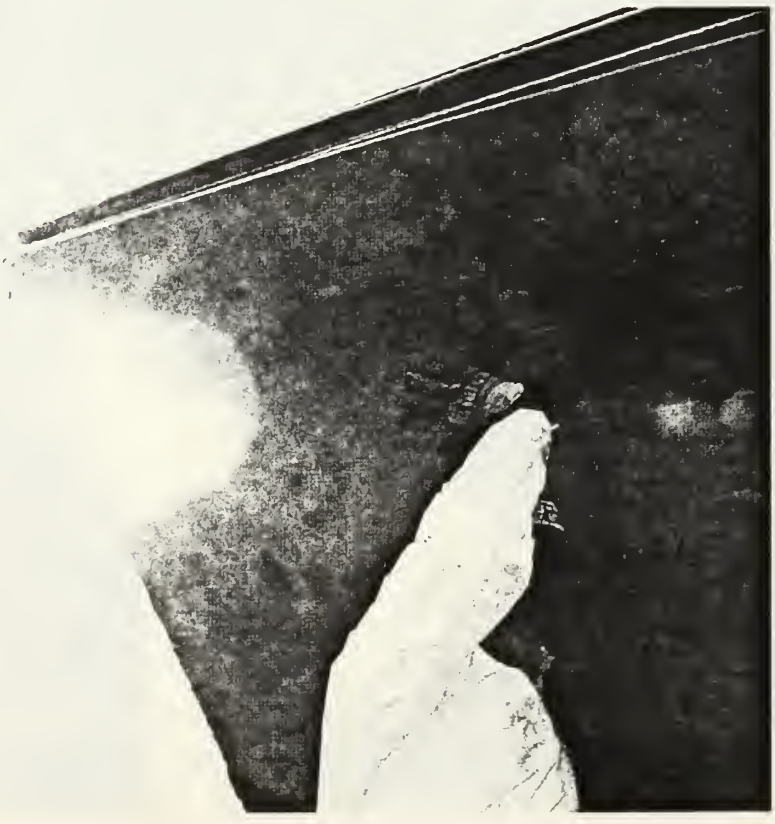
Warm-N-Dri board, a semi-rigid product made of Pink® Fiberglas® insulation, acts as a drainage medium to keep hydrostatic buildup from foundation walls. The board adds insulating value to foundation walls and protects the waterproofing membrane during construction and backfilling.



Typical installation of TUFF-N-DRI on concrete block wall.



Typical installation of TUFF-N-Dri on poured concrete wall.



y-applied Tuff-N-Dri membrane
the chances for breaks or open-
ie waterproof coating. It leaves
les or "fish mouths" in applica-
-N-Dri membrane is resilient and
strong adhesion to concrete.

e Durability

ri's resilient membrane resists
wth, bacterial and chemical
nlike many dampproofing prod-
-N-Dri will not break down as a
prolonged contact with water
And the membrane's superior
In properties allow Tuff-N-Dri to
or cracks over years of service.

Efficient Foundations

Dri board, available in 3/4, 1-3/16
3 inch thicknesses, provides
of 3.1, 5.0 and 10.0 respectively.
Dri board can be terminated at
extended to the sill plate. Com-
lysis of home energy use indicates
nsiderable portion of the typical
nergy load is represented by
ninsulated basements. Warm-N-
ed to the sill plate insulates the
ement wall and minimizes base-
rgy use.

Warm-N-Dri board provides a direct path for water percolating through the soil to a drain tile system. Hydrostatic buildup on the basement walls is reduced. Tuff-N-Dri applications require a positive foundation drain system.

Condensation Protection

Warm-N-Dri keeps foundation walls closer to the air temperature of the basement. This can help reduce condensation. Reduced condensation can ensure a less humid, more comfortable basement. The placement of Warm-N-Dri on the wall's exterior can also help reduce the risk of damage due to freeze/thaw cycles

Foundation Protection

Warm-N-Dri board will protect the waterproofing membrane from damage caused by backfilling or damage from other construction trades. The compressibility of the Warm-N-Dri board will also absorb moderate soil expansion and help protect the basement wall.

Versatile, Rapid Installation

The Tuff-N-Dri system can be applied when ambient temperatures are as low as 20 °F, allowing for fewer construction delays. Tuff-N-Dri may be applied on poured concrete and block foundations. On poured concrete basements, the Tuff-N-Dri system can be applied as soon as the forms are removed, and on concrete block basements, as soon as the mortar is dry. The Tuff-N-Dri membrane does not require a primer coat. Spray application reduces labor costs normally associated with waterproofing.

Tuff-N-Dri, Warm-N-Dri, Pink and Fiberglas are registered trademarks of Owens-Corning Fiberglas Corporation

Certified Waterproofing Contractors
Owens-Corning's Tuff-N-Dri waterproofing system is available exclusively through a network of Certified Independent Waterproofing Contractors, trained and supported by Owens-Corning to ensure effective, professional installation.

10-Year Limited Warranty
When applied to residential below grade foundations by a Certified Independent Waterproofing Contractor, in conformance with Owens-Corning specifications and application instructions, the Tuff-N-Dri waterproofing system has a 10-year limited warranty. See the warranty for specific coverage and limitations.

Maintenance
Owens-Corning waterproofing products do not require maintenance as long as they are installed according to the manufacturer's recommendations.

Material Storage
Store Tuff-N-Dri liquid in an area where the material will not be exposed to heat sources for an extended period of time. Tuff-N-Dri liquid is flammable and should be stored away from sparks or flames.

Surface Preparation
The wall surface should be smooth and monolithic. Remove loose aggregate and sharp protrusions from the wall. Voids, spalled areas and exposed aggregate should be patched with a suitable mastic before spraying. The Tuff-N-Dri membrane does not require any priming or special preparation.

System Application
Tuff-N-Dri liquid is sprayed evenly over the entire foundation wall. After the surface has had adequate time to set-up, Warm-N-Dri board is applied over the waterproofing membrane. For detailed installation instructions contact the local Tuff-N-Dri marketing specialist.

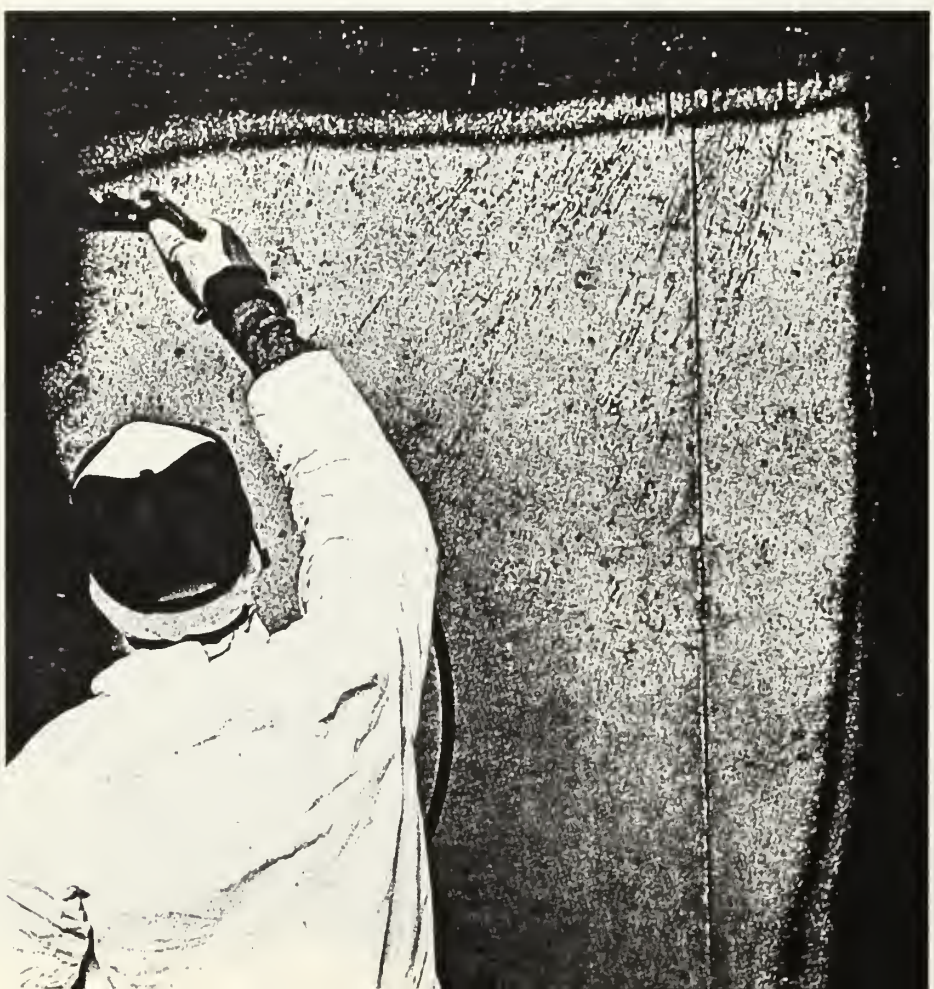
Limitations
Tuff-N-Dri waterproofing membrane should not be exposed to sunlight for more than 15 days.

Tuff-N-Dri membrane should not be applied to concrete having a surface temperature below 20 °F.

Warm-N-Dri board is required for all warranted Tuff-N-Dri system applications. Warm-N-Dri board must extend to the footing and connect through gravel fill or channels to a positive foundation drain system.

Availability and Cost
Owens-Corning waterproofing products are competitively priced and are available through a network of Certified Independent Waterproofing Contractors. For information concerning the nearest contractor, please call (419) 248-7550.

Membrane Description	
Type	Polymer-modifie liquid-applied me
Color	Black
Solids	66 (percent by w
Density	7.7 lb./gal.
Minimum Application Temperature	20 °F
Application	Airless spray
Coating Cure Time	16-24 hr.



rane Properties

ties	Typical Results	Test Methods
on to Concrete	Exceeds	ASTM C-836[1]
tion	800 percent	ASTM D-412
mperature Flexibility	Flexible to −10 °F	OCF Test[2]
Bridging Ability	Exceeds 10 cycles to 1/8 in. at −15 °F	ASTM C-836[1]
Vapor Permeance	0.30 perms for 40-mil dry coating (grain/ft² 2/hr. in Hg)	ASTM E-96
Water Absorption	Less than 1%	ASTM D-1228[3]
nce to Degradation	Good	ASTM E-154
rowth and Bacterial	No degradation	OCF Test[4]
nce to Accelerated cal Attack	Resistant to acids, salts, bases	OCF Test[5]
nce to Hydrostatic ft. of water)	Could not generate hydrostatic pressure	OCF Test[6]

cured at room temperature
proofing compound around 1 inch mandrel
ter soak 1 × 2 × 0 40 inch samples of waterproofing compound
was exposed to various soil organisms and no degradation was observed
ng compound soaked in solutions of hydrochloric acid, sulfuric acid, acetic acid, sodium hydroxide, calcium hydroxide, sulfate, sodium chloride-sodium sulfate and 4 percent ammonium hydroxide retains flexibility and elongation after

n-N-Dri board was applied to the Tuff-N-Dri membrane the water drained away at a faster rate than the surrounding ted, eliminating any hydrostatic buildup

Board Description

Type	Unfaced rigid Fiberglas® board
Color	Pink
Board Size	4 ft. × 8 ft. and 4 ft. × 4 ft.
Board Thicknesses	3/4 in., 1-3/16 in &. 2-3/8 in.

Board Properties

Properties	Typical Results	
Drainage Ability	Board Thickness	Gallons/Hour/ Lineal Foot
	3/4"	74
	1-3/16"	118
	2-3/8"	237
	Hydraulic Gradient of 1.0	
Thermal Resistance*	3/4 in.—R3.1 1-3/16 in.—R5.0, 2-3/8 in.—R10.0 (as manufactured)	

*Warm-N-Dri board was installed five years ago at Owens-Corning's Foundation Test Facility Since installation no loss of R-value has been measured

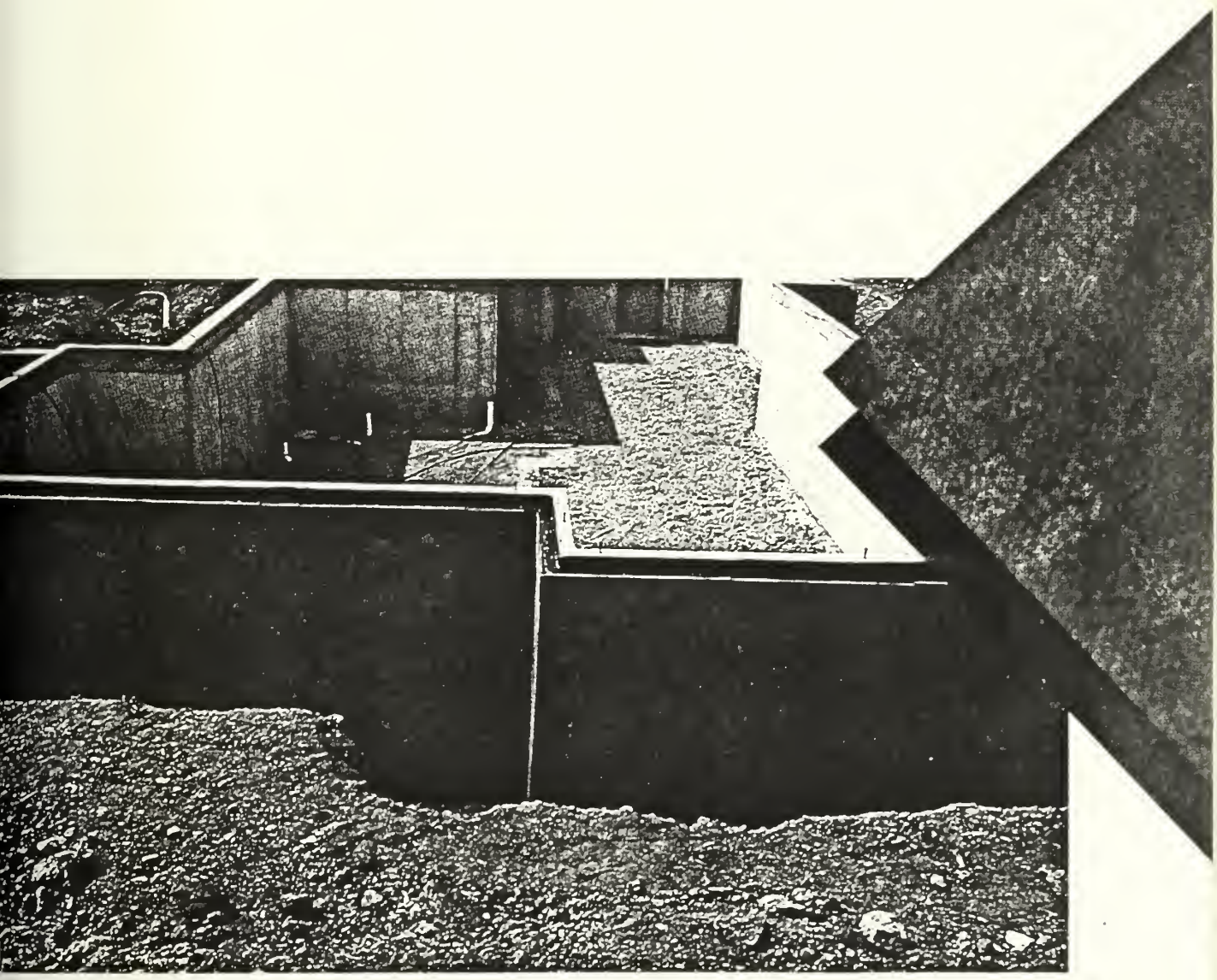
Board Properties

Compression Pressure lbs.sq. ft.	% Compression 3/4" 1-3/16" & 2-3/8"	Depth Thes Pressures Are Clay[1]	Wet S
200	4%	4 ft.	10
400	8%	8 ft.	20
600	11%	12 ft.	30
800	15%	16 ft.	40
1000	19%	20 ft.	50
1200	23%	24 ft.	60
1400	28%	28 ft.	70
2000	41%	40 ft.	100

At 65% compression, Warm-N-Dri board has the drainage capabilities of coarse sand
[1]Angle of Repose of 25° Density of 120 lbs /cu ft
[2]Angle of Repose of 46° Density of 122 lbs /cu ft

uff-N-Dri®

07100/OWE
Buyline 2159



Regional Tuff-N-Dri® Marketing Specialist Offices

Chicago
312-480-4354

Atlanta
404-956-1465

Scarsdale
914-472-3400

Washington, D.C.
301-390-6900

OWENS/CORNING FIBERGLAS TRADEMARK

Owens-Corning Fiberglas Corp.
Foundation Systems
Fiberglas Tower, Toledo, Ohio 43659
419-248-7550

ANUFACTURER
wens-Corning Fiberglas Corporation
undation Systems
berglas Tower
ledo, Ohio 43659
one: (419) 248-7550

MANUSPEC®

This Manu-Spec presents the manufacturer's suggested proprietary specification in conformance with the CSI 3-Part Section Format. The manufacturer is solely responsible for content and references.

SECTION 07125
MODIFIED ASPHALT SPRAY APPLIED WATERPROOFING SYSTEM

RT 1 GENERAL

01 SECTION INCLUDES

A. Waterproofing

B. Protection board

02 RELATED SECTIONS

A. Section 03300—Concrete

B. Section 04200—Masonry

03 REFERENCES

A. Waterproofing membrane shall meet or exceed the following industry standards.

1. ASTM C836: Testing for High Solids Content, Cold Liquid-Applied Elastomeric Waterproofing Membrane for use with Separate Wearing Course.
2. ASTM D412: Tests for Rubber Properties in Tension.
3. ASTM D1228: Testing Asphalt Insulating Siding Surfaced with Mineral Granules.
4. ASTM E96: Testing Materials for Water Vapor Transmission.
5. ASTM E154: Testing Materials for Use as Vapor Barriers Under Concrete Slabs and as Ground Cover in Crawl Spaces.

04 DELIVERY, STORAGE, AND HANDLING

A. Delivery: Delivered to site with original manufacturer's labels clearly identifying TUFF-N-DRI® membrane and WARM-N-DRI® board.

B. Storage and Handling: Keep free of debris and foreign matter.

05 ENVIRONMENTAL REQUIREMENTS

A. Install TUFF-N-DRI membrane when substrate is above 20°F.

B. Install TUFF-N-DRI membrane when surfaces are dry and inclement weather is not prevalent.

RT 2 PRODUCTS

01 MANUFACTURER

A. OWENS-CORNING FIBERGLAS CORPORATION, Foundation Systems, Fiberglas Tower, Toledo, Ohio 43659.

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ction Specifications Institute, Inc., Alexandria, VA 22314

August 1987
(Supersedes February 1986)

2.02 MATERIALS

A. Polymer-Modified Asphalt Fluid-Applied Waterproofing Membrane: TUFF-N-DRI membrane meeting and conforming to the following tests and values.

Properties	Typical Results	Test Methods
Color	Black	
Adhesion to Concrete	Exceeds	ASTM C836
Elongation	800 percent	ASTM D412
Low Temperature Flexibility	Flexible to −10°F	
Crack Bridging Ability	Exceeds 10 cycles to 1/8 in. at −15°F	ASTM C836
Water Vapor Permeance	0.15 perms for 40-mil dry coating (grain/ft.²/hr. in Hg)	ASTM E96
Liquid Water Absorption	0.3 percent (wt.)	ASTM D1228
Resistance to Degradation in Soil	Good	ASTM E154
Mold Growth and Bacterial Attack	No degradation	
Resistance to Accelerated Chemical Attack	Very resistant to acids, salts, bases	

B. Protection/Drainage/Insulation Board: WARM-N-DRI board meeting and conforming to the following tests and values.

Type:	Unfaced rigid fiberglass board	
Physical Appearance:	Pink, Unfaced	
Board Size:	4 ft. x 4 ft., 4 ft. x 8 ft.	
Board Thicknesses:	5/8 in., 1-3/16 in. & 2-3/8 in.	
Thermal Resistance:	5/8 in. - R 2.5 (as manufactured) 1-3/16 in. - R 5.0 (as manufactured) 2-3/8 in. - R 10.0 (as manufactured)	
Drainage Ability: Hydraulic gradient of 1.0	Board Thickness 5/8 in. 1-3/16 in. 2-3/8 in.	Gallons/Hour/Lineal Foot 62 118 237

PART 3 EXECUTION

3.01 EXAMINATION

A. Verify that the substrate is smooth and free of voids, spalled areas, loose aggregate, sharp protrusions, form fins, and exposed course aggregate areas.

B. Beginning installation means installer accepts existing conditions.

3.02 INSTALLATION—POLYMER-MODIFIED-ASPHALT FLUID APPLIED MEMBRANE

A. Apply TUFF-N-DRI membrane to a clean, smooth and dry concrete surface.

B. Extend TUFF-N-DRI membrane down walls from finished grade line to top of footing and extend over top of footing.

3.03 INSTALLATION—PROTECTION/DRAINAGE/INSULATION BOARD

A. Apply WARM-N-DRI board vertically using spot areas of TUFF-N-DRI membrane as an adhesive on the dry membrane.

B. WARM-N-DRI board must extend down to the foundation footing and connect through gravel or channels to a positive drain system.

End Of Section

Pub. No. 0-TD-14522
Litho in U.S.A., July 1987

R.O.I.C.C.
KINGS BAY
GA.
21 SEP 87 10 14

SPEC-DATA®

This Spec-Data Sheet conforms to editorial style prescribed by The Construction Specifications Institute. The manufacturer is responsible for technical accuracy.

ODUCT NAME

N-DRI® Exterior Founda-
Vaterproofing Membrane
Applied)
-N-DRI® Protection/Drain-
sulation Board

NUFACTURER

S-CORNING FIBERGLAS
RPORATION
tive Coatings Business
las Tower
, Ohio 43659
: (419) 248-7550

ODUCT DESCRIPTION

lc Use: TUFF-N-DRI
RPROOFING MEMBRANE
ingle component spray
d waterproofing for below
concrete or masonry
ation walls, planters, and
el walls. TUFF-N-DRI
BRANE forms a tough,
nt elastomeric film that will
cracks common to or that
in concrete substrates.
TUFF-N-DRI MEMBRANE
the application of the water-
ng membrane to occur as
as the concrete forms are
or the block mortar is dry.
nonolithic coating on the
ate eliminates any concern
nkles or "fish-mouths" in
terproofing membrane.
RM-N-DRI BOARD is used
otect the waterproofing
rane on vertical surfaces
construction and backfill-
ARM-N-DRI BOARD acts
s a drainage medium to
ydrostatic pressure build-
n the foundation walls. The
ttribute of using WARM-N-
)ARD is that it adds insulat-
lue (R-5* per nominal 1"
ess). The board is adhered
e of the TUFF-N-DRI
BRANE or TUFF-LOK™
IC with no mechanical
rs needed.

itations: TUFF-N-DRI
RPROOFING MEMBRANE
not be applied where it will
osed to sunlight for more than 15 days. The TUFF-N-DRI MEMBRANE should only be applied to the substrate when the substrate has a surface temperature above 20°F (Winter Grade).

WARM-N-DRI BOARD, when installed below grade, must have an exterior drain system. If WARM-N-DRI BOARD is installed above grade it must have an exterior covering.

WARM-N-DRI BOARD is required as protection for TUFF-N-DRI MEMBRANE on foundations 10 feet or more below grade. Also included are areas of high water tables, expansive clays, or other areas where the backfill will damage the unprotected membrane.

Composition and Materials: TUFF-N-DRI WATERPROOFING MEMBRANE consists of polymer-modified asphalt that is spray applied.

WARM-N-DRI BOARD is an unfaced, rigid fiber glass board having protection, drainage, and insulation characteristics.

Sizes: WARM-N-DRI BOARD is available in 4' x 4' and 4' x 8' boards with nominal thicknesses of 5/8", 1-3/16", and 2-3/8".

4. TECHNICAL DATA

TUFF-N-DRI Membrane

Properties	Typical Results	Test Methods
■ Color	Black	
■ Adhesion to Concrete	Exceeds	ASTM C836[1]
■ Elongation	800 percent	ASTM D412
■ Low Temperature Flexibility	Flexible to −10°F	See 2
■ Crack Bridging Ability	Exceeds 10 cycles to 1/8 in. at −15°F	ASTM C836[1]
■ Water Vapor Permeance	0.15 perms for 40-mil dry coating (grain/ft.² /hr. in Hg)	ASTM E96 water method
■ Liquid Water Absorption	0.3 percent (wt.)	ASTM D1228[3]
■ Resistance to Degradation in Soil	Good	ASTM E54
■ Mold Growth and Bacterial Attack	No degradation	See 4
■ Resistance to Accelerated Chemical Attack	Very resistant to acids, salts, bases	See 5
■ Resistance to Hydrostatic Head (ft. of water)	Could not generate hydrostatic pressure	See 6

Footnotes:
1. Membrane cured at room temperature.
2. Bend waterproofing compound around 1 in. mandrel.
3. 72 hour water soak 1 x 2 x 0.40 inch samples of waterproofing compound.
4. OCF test #M06A.
5. Waterproofing compound soaked in 2 percent solutions of hydrochloric acid, sulfuric acid, acetic acid sodium hydroxide, calcium hydroxide, magnesium sulfate, sodium chloride-sodium sulfate and 4 percent ammonium hydroxide retains flexibility and elongation after 8 months.
6. When 1 3/16 in. of WARM-N-DRI board was applied to the TUFF-N-DRI membrane the water drained away at a faster rate than the surrounding soil percolated eliminating any hydrostatic build-up.

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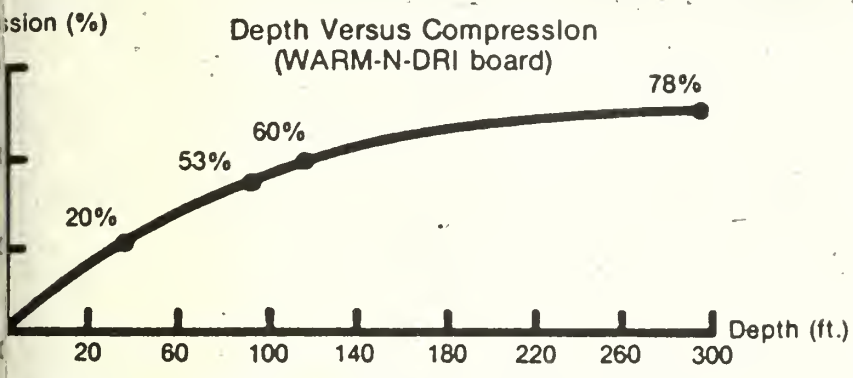
-N-DRI Board

Type:	Unfaced rigid fiber glass board.
Physical Appearance:	Pink, Unfaced
Board Size:	4 ft. × 8 ft., 4 ft. × 4 ft.
Board Thicknesses:	5/8 in., 1 3/16 in. & 2 3/8 in.
Thermal Resistance:	1 3/16 in. – R 5.0 (as manufactured) 2 3/8 in. – R 10.0 (as manufactured)
Drainage Ability	850-1000 Darcies (as manufactured) Comparison: ■ Gravel – 200 + Darcies ■ Sand – 15-200 Darcies



At 65% compression, WARM-N-DRI board has the drainage capabilities of coarse sand.

TALLATION

ge: TUFF-N-DRI MEM-E should be stored in a dry here the temperatures do eed 90°F for an extended of time. Store all materials om sparks or flames.

ce Preparation: Surface smooth and free of voids, areas, loose aggregate, rotrusions, form fins, and d course aggregate areas.

lication: TUFF-N-DRI RANE may be applied to tion walls without the use primer as soon as the have been removed. If re found in the coating, p the area with TUFF-N-EMBRANE using a brush spray coat.

ection of Membrane: -N-DRI PROTECTION/ NAGE/INSULATION D is recommended for all N-DRI MEMBRANE appli- but is required for TUFF-MEMBRANE applications s of expansive clays, high ables, foundations 10 feet or more below grade and in other areas where backfill will damage the unprotected membrane. WARM-N-DRI BOARD will protect the waterproofing membrane during construction and backfilling. Also, WARM-N-DRI BOARD will provide drainage directly to the drain tile as well as insulate the foundation.

WARM-N-DRI BOARD should extend all the way to the footing and connect through a gravel fill to the positive drainage system.

WARM-N-DRI BOARD may be applied over TUFF-N-DRI MEMBRANE approximately 3 to 4 hours after installation of the waterproof membrane.

6. AVAILABILITY AND COST

Availability: TUFF-N-DRI MEMBRANE and WARM-N-DRI BOARD are available through a national network of Owens-Corning Certified Independent Commercial Waterproofing Contractors.

Cost: TUFF-N-DRI MEMBRANE and WARM-N-DRI BOARD are competitively priced. For further information, call Owens-Corning at (419) 248-7550.

7. WARRANTY

Owens-Corning warrants that TUFF-N-DRI MEMBRANE and WARM-N-DRI BOARD exterior foundation products, if installed in accordance with our instructions, will meet our published specifications and will be free from defects in material or workmanship for a period of one (1) year following date of original delivery by us.

Should any material be otherwise than as warranted, our liability under this warranty shall be limited to replacement of such material to the point of our original delivery. The foregoing constitutes our exclusive obligation and we make no express or implied warranties, or any warranty or merchantability or fitness for any particular purpose whatsoever, except as stated above. In no event shall Owens-Corning Fiberglas Corporation be liable for incidental, indirect, or consequential damages. This Warranty is expressly limited to the contractors, and is not intended as a consumer warranty.

8. MAINTENANCE

None required.

9. TECHNICAL SERVICES

Owens-Corning waterproofing products are backed by a technical support staff that is available to provide information and assistance In selection or reviewing your waterproofing and insulation requirements.

10. FILING SYSTEMS

SPEC-DATA II®
SWEETS ARCHITECTURAL CATALOG FILE

Additional product information available upon request to OWENS-CORNING at (419) 248-7550.

Pub. No. 3-TD-13815. Litho in U.S.A., February 1986.

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EXTERIOR FOUNDATION WATERPROOFING SYSTEM

Owens-Corning Fiberglas CERTIFIED Independent Waterproofing Contractor TM

ion Procedures
N-Dri® Exterior Foundation Waterproofing System

rning Fiberglas Exterior n Waterproofing

Owens-Corning Fiberglas has developed a unique, polymer-modified asphalt coating called **Tuff-N-Dri** and a protection-drainage-insulation board called **Warm-N-Dri**® which as a system provide Exterior Foundation Waterproofing. The **Tuff-N-Dri** material provides a highly elastomeric waterproof membrane when applied to block, parged block and poured concrete foundations. **Tuff-N-Dri** coating has demonstrated excellent water impermeability.

The polymer-modified asphalt coating can be easily and effectively applied by following the Owens-Corning Fiberglas recommended installation procedures. **Warm-n-Dri** is a dense fibrous board that provides protection against harsh backfill, has drainage equivalent to gravel, and provides thermal protection to the foundation. Care must be taken to assure all aspects of proper waterproofing technique are used. Proper waterproofing technique includes adequate surface preparation of footing and walls prior to coating, as well as the use of properly installed positive drainage systems and surface grading.

Handling s


A.


B.


C.

Follow the safety precautions listed below, as well as those listed on the **Tuff-N-Dri** product container. In addition, installers should follow safety precautions outlined in the appropriate spray equipment operation procedures.

1. Do not use indoors. Solvent vapors may accumulate, resulting in a health or fire hazard.
2. **Tuff-N-Dri** coating is **flammable**. Do not smoke or expose coating or its vapors to other ignition sources during handling or spraying operations. A fire or explosion may result.
3. Do not breathe coating vapors. Vapors are harmful. Use respiratory equipment when spraying. Minimize exposure to vapors by spraying from outside the excavation whenever possible. Recommendations for respirators are as follows:
   A. When spraying from outside the excavation, minimum protection should consist of a NIOSH approved disposable organic vapor respirator, such as the 3M 8712 or equivalent.
   B. If spraying from within an open excavation (more than four feet wide or below chest), minimum protection again should consist of a NIOSH approved disposable organic vapor respirator, such as the 3M 8712 or equivalent. A used respirator should be replaced when the operator detects solvent odor through the respirator.
   C. If spraying within a narrow excavation (less than four feet wide) which is above the operator's chest, additional protection is required. In this case, wear an approved full face respirator with organic vapor canister, such as MSA catalogue number 457087 or equivalent. A used canister should be replaced when the operator detects solvent odor through the respirator.

Follow manufacturers' specifications and limitations on use of all respirators.

ENCLOSURE (3)

EXTERIOR FOUNDATION WATERPROOFING SYSTEM

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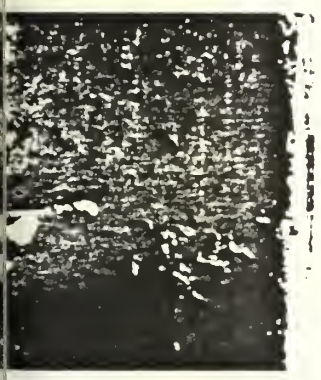


neycomb

Any
ged.

4. Be sure spray equipment is electrically grounded, to prevent static electrical discharge and possible explosion.
5. Never direct high pressure spray at any part of the human body. Relieve pressure before servicing equipment. Be sure all equipment has the proper pressure ratings.
6. Wear adequate eye protection while spraying. If coating comes in contact with the eyes, flush with clean water and consult physician.
7. Avoid contact with skin. If necessary, remove from skin with industrial-type hand cleaner.
8. Wear gloves when spraying hot coating.
9. Follow applicable local, state, and federal regulations regarding storage, transportation and handling of flammable liquids.
10. Take proper precautions when handling flammable clean-up solvents.

General Installation Procedures – New Construction

Owens-Corning Fiberglas installation procedures must be followed.

1. Foundation walls and footing must be dry prior to application of the **Tuff-N-Dri** coating. Coating must not be applied over standing water.
2. Remove dirt and debris from footing and walls with a stiff masonry brush or broom. If necessary, scrape loose mortar from walls and footing with a metal scraper.
3. Repair all cracks in walls and footing with non-shrinking grout.*
4. Parge honeycombed areas and other voids in the surface prior to coating with a non-shrinking grout.*
5. Solvent based asphalt mastics may be used to repair voids around tie holes, recessed ties, and other small voids. The compatibility of the mastic with the **Tuff-N-Dri** coating may be determined by applying a film of mastic to a substrate, allowing the film to cure, and coating with **Tuff-N-Dri**. If the materials are incompatible, the **Tuff-N-Dri** coating will not adhere to the mastic, and can be easily peeled from the mastic.
6. Apply **Tuff-N-Dri** at an ambient temperature above 20°F. Prior to spray operation, heat coating to 120-160°F. For Complying Solvent, heat coating to 140-180°F prior to spray operation.
7. Install **Warm-N-Dri** protection, drainage, insulation board over the **Tuff-N-Dri** membrane within 1 to 3 hours after application of the membrane. Press the Warm-N-Dri boards firmly into place, if additional adhesion is needed, a light coat of **Tuff-N-Dri** can be sprayed onto the wall and immediately press on the **Warm-N-Dri** boards.

   Note: For additional information, see Protective Coatings Business Technical Bulletin #3-2 Installation Instructions for **Warm-N-Dri** boards over **Tuff-N-Dri** membrane.

   Note: Do not dilute **Tuff-N-Dri** coating or mix it with any other material.

*Example formulations for nonshrinking grouts
1 A 50 50 mixture of Portland Cement and a hydraulic cement, e g Thoroseals Waterplug, Sakcretes Quickplug
2 Thorite cement patching compound

Installation Procedures for Tuff-N-Dri® Exterior Foundation Waterproofing System

al procedures for poured
walls are given below
ıre 1).

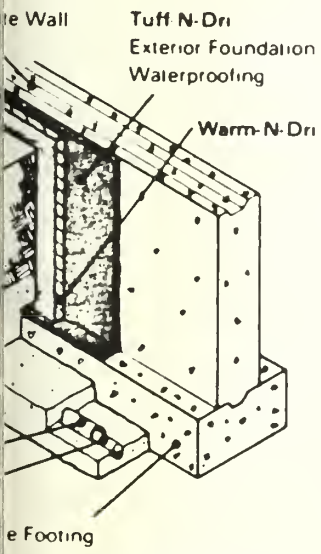
at least 16 hours cure
ɔn freshly poured concrete
o spraying. Additional
nay be required in cool
ıer.

ɔt apply to frozen concrete.

ve wall ties prior to appli-
. Fill any large voids with
-shrinking grout.*

coating at a rate of not
than 25 square feet per
ı.

ɔncrete foundation must
such strength and design
ure structural integrity.
ılt the American Concrete
ıte and local building code
ıtions.

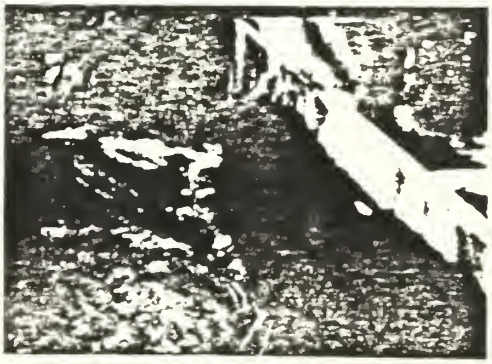


*ınstallation of the **Tuff-N-Dri***
lation waterproofing system
ıcrete wall

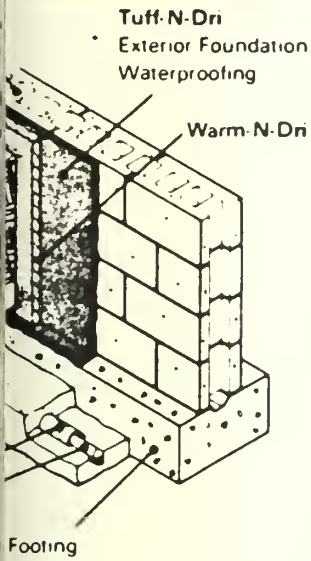
9. Additional procedures for concrete block walls are given below (see Figure 2, 3).
   A. Mortar joints must be struck (made flush) to provide a void-free bonding surface.
   B. Allow at least 16 hours cure time on mortar joints prior to spraying. Additional time may be required in cool weather.
   C. If local building code permits, the block need not be parged prior to installation of the **Tuff-N-Dri/Warm-N-Dri** waterproofing system.
   D. The mortar must be type M (high strength) or type S (moderate strength) by ASTM C270.
   E. Follow local code requirements on parging.
   F. Apply coating at a rate of not more than 25 square feet per gallon on parged concrete block, and not more than 20 square feet per gallon on unparged block.
   G. The concrete block foundation must be of such strength and design to insure structural integrity. Consult the National Concrete Masonry Association and local building code requirements.

Coating Spray-applied

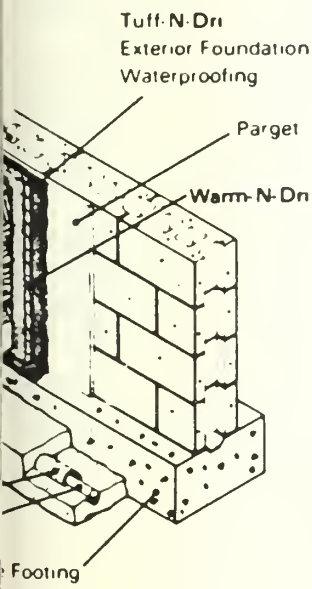
Equipment Cleaned for Next Application



Typical System Installation



nstallation of the
erior foundation water-
m on concrete block wall



nstallation of the
terior foundation water-
m on parged concrete

10. During spray operations, pay close attention to irregularities in the surfaces to be coated. Adjustments in spray angle and additional coating may be necessary to assure that all surfaces are adequately coated. Examples of irregularities are:
    - Joints between footing and walls
    - Joints between blocks
    - Form joints
    - Cold joints
    - Honeycombed surfaces
    - Wall tie penetrations
    - Utility, vent, and chimney penetrations
    - Simulated brick surfaces
11. After completing spray application of foundation, check for areas which were missed and also those which are visibly thin. Apply a touch-up coat to these areas. If necessary, a paint brush can be used to apply **Tuff-N-Dri** coating to small areas which need additional coating. Application with brush should only be done after the initial coating has set-up sufficiently to allow a brushing action without damaging the membrane. Also check for pooled areas of coating on footings and brick ledges. These areas should be brushed out to a thickness no greater than ⅛ inch so that proper cure can occur.
12. Installation of draintile and backfilling may proceed immediately after the installation of the **Warm-N-Dri** board. Coated surfaces should be covered within 15 days. Long-term exposure of the **Tuff-N-Dri** membrane to sunlight may be detrimental to performance of coating.
13. Drainage tile **must** be installed per manufacturer's recommendations to provide for removal of water from foundation walls and footing.
14. Grading is required to direct surface water away from the structure.

Equipment for Application

Appropriate airless spray equipment is critical to **Tuff-N-Dri** coating performance. Graco Twin Ball Hydraulic pump has been used extensively in the field.

OWENS-CORNING FIBERGLAS
Protective Coatings Business
Fiberglas Tower
Toledo, Ohio 43659

Dewberry & Davis

Architects Engineers Planners Surveyors

P.O.I.C.C.
KINGS BAY
GA.

28 MAY 87 10 57 U

8401 Arlington Boulevard
Fairfax, VA 22031-4666
703 849-0100

May 15, 1987

Department of the Navy
Resident Officer in Charge of Construction, Industrial
Naval Facilities Engienering Command Contracts, Trident
Naval Submarine Base
Kings Bay, Georgia 31547-7200

Attn: Lieutenant T.F. Biggins

RE: Post Construction Awards Services
Limited Area Missile/Motor Magazine
Naval Submarine Base, Kings Bay, Georgia
Construction Contract N68248-84-C-4147
Architect Engineer Contract N68248-83-C-0305, Supplement No. 15
In-Office Consulatation No. 17

Gentlemen:

On May 8, 1987, we received your letter dated May 7, 1987, forwarding data for contractor's proposed waterproofing system and drainage board.

This was reviewed by Mr. Glen Bates of this office.

Based on the data submitted, the proposed waterproofing system and drainage board is acceptable. It is our understanding that the concrete surface will not be coated with Thoroseal as required by Section 0300 of the specifications.

With this in-office consultation we have gone beyond the scope of work for Supplement No. 15 by two consultations.

ENCLOSURE (4)

Fairfax VA
Annapolis MD
Landover MD
Leesburg VA
Morristown TN
Raleigh NC

The Scope of Work for this Supplement states that "...in-office consultations in excess of 15 total shall be deemed as beyond the scope of this supplement". A supplement to the contract is required to cover any future in-office consultations required by ROICC.

Very truly yours,

DEWBERRY & DAVIS

JPF/GB/krs

cc: OICC Trident, Code 0513
OICC Trident, Code 04

Brunswick
CORPORATION

PO Box 707
St Marys Georgia 31558

912 882-6300

Ltr. No. 8220-87-3038

8 June 1987

fficer in Charge of Construction
aval Facilities Engineering
ommand Contracts, TRIDENT
93 Point Peter Road
t. Marys, Georgia 31558

ttn: CDR R. E. Terry
ROICC-Industrial

e: Contract N68248-82-C-0220, Engineering
Services for Construction Inspection, a
Facilities Maintenance Support System, and
Related Professional Engineering Services

ubj: Recommendation on Proposed Material Variance
Contract: N68248-84-C-4147
FY87 Missile Motor Magazines

Gentlemen:

This letter is written in response to your Service Request dated 6 May 1987, which requests a recommendation concerning the Contractor's Proposed Variance regarding a proposed new waterproofing system for the magazines, consisting of the Owens Corning Fiberglas products "Tuff-N-Dri" and "Warm-N-Dri." Our analysis compares the proposed materials with the Vulkem products used on previous Contract 83-C-3137.

A. Will the proposed substitution work?

Yes.

B. Will the proposed substitution result in work of better or equal quality?

Better.

C. Will the proposed substitution cost more or less?

More.

ENCLOSURE (5)

D. Discussion:

Specification Section 07120 calls for fluid-applied waterproofing membrane conforming to ASTM C-836. Since the proposed Tuff-N-Dri waterproofing product is a fluid-applied membrane conforming to ASTM C-836, we do not see the proposed product as a variance from the contract requirements. The Vulkem 201 and 222 used in the Contract 83-3137, SWF Magazines, is also a fluid-applied membrane.

In comparing the two products, Vulkem 201 and Tuff-N-Dri, the following differences are noted:

1. Vulkem 201 is a bitumen-modified polyurethane while the Tuff-N-Dri is a polymer-modified asphalt.

2. Vulkem 201 is cold applied, while Tuff-N-Dri is hot applied. This can help result in better adhesion to concrete.

3. Both Vulkem and Tuff-N-Dri comply with ASTM C-836 and have similar properties.

4. Both Vulkem and Tuff-N-Dri comply with the contract Specification Section 07120, for the application of 60±5 mils, but neither Vulkem nor Tuff-N-Dri complies with the rate of application of 85 mils required by the FSS-M18 Guide Specification for Section 07120 (Fluid-Applied Elastomeric Waterproofing for Earth Covered Concrete Arch magazines).

5. Contract Specification Section 07120 calls for a protection board 1/8 inch thick minimum, compatible with the fluid-applied membrane. The protection board proposed for the Vulkem system does not comply with this requirement. The protection board proposed with the Tuff-N-Dri system is clearly superior and complies with the specification requirement.

6. Neither Vulkem nor Tuff-N-Dri indicates the compatibility of the products with curing compounds.

D. Recommendation:

Approve use of Tuff-N-Dri/Warm-N-Dri.

lease call should you have any questions regarding the above recommendation.

ery truly yours,

/mvw
ttachments
c: ROICC (2)

Concrete Solutions, Inc.
Waterproofing, Deck & Special Coating Membranes & Applications

P.O. BOX 19086
rmingham, Alabama 35219

Michael L. Smith, President
(205) 979-0223

April 9, 1987

Construction Company
.O. Box 8270
yler, Texas 75711

ttention: Gordon Campbell

e: Missile Motor Magazines

ear Gordon:

lease find enclosed the following submittal data for the Owens-Corning Fiberglas uff-n-Dri and Warm-n-Dri System. Also enclosed is a letter of conformance from wens-Corning Fiberglas and several references.

he Owens-Corning Fiberglas Tuff-n-Dri and Warm-n-Dri System is a hot applied aterproofing system. The Tuff-n-Dri is heated to 145 to 200 degrees and sprayed pplied with a high pressure airless sprayer. The wet mileage thickness of the aterial varies from 50 to 60 mils.

he dry film thickness is approximately 35 to 40 mils. After the membrane has een applied it becomes tacky to the touch and the Warm-n-Dri will be imbedded nto the membrane.

he Tuff-n-Dri and Warm-n-Dri System does not require that the concrete surface e parged with Thoro-Seal or any other cementitious finish. The tie holes, honey-ombs or irregularities in the concrete need to be parged, flush with the surface efore the Tuff-n-Dri is applied.

he Tuff-n-Dri does not require any cure time of the concrete. Therefore, the oisture meter which was required in the specifications is no longer a factor. he Tuff-n-Dri can be sprayed on green concrete. The other material specified nd used on the previous 15 missile motor magazines required a 28 day cure time n order to allow the moisture to escape.

here are several advantages in the Owens-Corning Fiberglas Tuff-n-Dri and Warm-n-ri System and they are as follows:

TUFF-N-DRI

1. Tuff-n-Dri does not need a primer or special treatment of the concrete.
2. Tuff-n-Dri can be sprayed on green concrete after tie holes, honeycomb or irregularities in the concrete have been parged.
3. Hot sprayed applied application ensures superior adhesion verses cold applied products.
4. Tuff-n-Dri has an elasticity or elongation of 800% which most membranes

ENCLOSURE (6)

do not have. This is very important for bridging stress and shrinkage cracks.

ohn Daugherty, technical representative for Owens-Corning Fiberglas looked at the ype of form release and curing compound that was being applied and said it is ompatible with the Tuff-n-Dri.

WARM-N-DRI

1. The specified system will only drain 4 gallons of water per minute. The Warm-n-Dri will drain 11 to 12 gallons of water per minute.
2. The Warm-n-Dri board drains to the outside face of the board down to the footing drain. The other drainage media drains to the inside against the waterproofing membrane.
3. The Warm-n-Dri is a drainage board which has the drainage capabilities of 2 feet of coarse sand.
4. The Warm-n-Dri System offers a insulation value. The thicker the board the greater the R value.
5. The Warm-n-Dri serves as the protection coarse for the Tuff-n-Dri fluid applied waterproofing system.
6. The Warm-n-Dri System is butted together and not lapped so you don't have the expensive waste in lapping the material.
7. The Warm-n-Dri board keeps the foundation walls close to air temperature of the basement interior. This reduces condensation which is extremely important for this project since missiles will be stored there.

he Owens-Corning Fiberglas Tuff-n-Dri and Warm-n-Dri System offers the Owner nd General Contractor a single source responsibility for the waterproofing and rainage board. No other manufacturer can offer this since no other manufacturer akes a waterproofing membrane and drainage media. Owens-Corning Fiberglas will ffer a 3 year written guarantee for labor and material.

he application procedure for the Owens-Corning Fiberglas Tuff-n-Dri and Warm-n-Dri ystem is as follows:

As soon as the forms are removed and the honeycombs, tie holes and irregularities are parged smooth and the parge dried. Then the Tuff-n-Dri is heated and sprayed applied directly to the concrete substrate without the use of primers. After the Tuff-n-Dri becomes tacky approximately 1 to 3 hours then the Warm-n-Dri is embedded into the Tuff-n-Dri. This is the finished product.

e look forward to working with you on this project, if you have any questions, lease advise.

hanking you in advance,
oncrete Solutions, Inc.

pril 9, 198

. Michael Smith
oncrete Solutions
076 Columbiana Road
irmingnam, AL 35216

ear Michael:

his letter is to certify that Tuff-N-Dri Waterproofing made b
vens-Corning Fiberglas meets the following physical requirements set
ut in C-836; the Material Requirement, the Stability Requirement Test,
he Low Temperature Flexibility and Crack Bridging Test, the Film
hickness on Vertical Surface Test and the Adhesion-in-Peel After Water
mmersion Test.

incerely,

Concrete Solutions, Inc.
Waterproofing, Deck & Special Coating Membranes & Applications

P.O. BOX 19086
irmingham, Alabama 35219

Michael L. Smith, President
(205) 979-0223

April 9, 1987

Construction Company
0. Box 8270
ler, Texas 75711

tention: Gordon Campbell

: Missile Motor Magazines

ar Gordon:

e following are a list of references:

Walker CRSS - (General Contractor)
Randy Newton
Denver Office
303-329-0321
Project - Concourse E Stapleton International Airport - Denver

Niles Bolton & Associates (Architect)
Jim Johnson
Atlanta Office
404-231-0770
Project - Has used Owens-Corning Fiberglas System on numerous projects.

Jack Bays, Inc. (General Contractor)
Lynn Bays
McClain, Virgina
703-365-2600
Project - Has used Owens-Corning Fiberglas System on numerous projects.

Harvey Construction Company (General Contractor)
Dick Moore
Bedford, New Hampshire
603-668-3100
Projects - Has used Owens-Corning Fiberglas System on numerous projects.

McDevitt & Street Company
Ray Morgan
Atlanta, Georgia
404-993-4300
Project - Compri Hotel Cumberland - Atlanta, Georgia.

Harbert International, Inc.
Craig Beatty
Birmingham, Alabama
205-324-7065
Project - Parking Deck #7

Harbert International, Inc.
Gary Savage
Durham, North Carolina
919-682-1630
Project - Durham Centre - Durham, North Carolina

you have any questions, please advise.

nking you in advance,
ncrete Solutions, Inc.

OWENS CORNING
FIBERGLAS

OWENS-CORNING FIBERGLAS CORPORATION

P. O. BOX 105060, ATLANTA, GEORGIA 30348
PHONE: (404) 956-1465

May 1, 1987

Mr. Gordon Campbell
C Construction
P.O. Box 8270
Tyler, Texas 75711

Dear Mr. Campbell:

This letter is intended as a response to the questions raised as regards installation of the Tuff-N-Dri Waterproofing System on the Kings Bay Motor Missile Magazines. Each question is listed with its appropriate response.

1) How do we measure millage thickness?

   Through use of a wet film thickness gauge, Model No. 790015 as manufactured by Nordson Corporation, Amherst, Ohio or K.J. Knoepfler Company, Cincinnati, Ohio.

2) What assurance is there that Tuff-N-Dri Waterproofing will be applied at 60-mil wet thickness and 40-mil cured thickness?

   The installed millage is calculated from the coverage rate. On poured walls our coverage will average 25 square feet/gallon with resultant 64.2 wet mil thickness.

   Since Tuff-N-Dri on average is 70% solids (and using a density correction factor of .064), the average cured millage will be 42.1 mils.

   Whenever a one coat application does not achieve the desired wet mil thickness due to "sagging", a second coat can be applied to achieve the desired thickness.

3) Will installation of the drainage/protection board effect the waterproofing millage or cure rate?

   There will be very little change if any to the waterproofing membrane during board installation. Some leveling may occur if the surface is irregular. Since Warm-N-Dri breathes, its effect on the Tuff-N-Dri cure rate is immeasurable.

4) Under 3 feet of wet sand, how much compression occurs on the Warm-N-Dri board and what effect does this compression have on the drainage capacity?

Compression of 5/8" Warm-N-Dri under three feet of wet sand is approximately 3% or .002". The drainage capacity is likewise reduced by 3%. The amount of compression due to depth is virtually a straight line regression with results of 6.9% at 10', 13.9% at 20' and so on. Obviously, 3' of depth has very little impact on the boards drainage ability.

5) Where and what is the history of Warm-N-Dri installation?

Initial test boards were buried in 1951 in Granville, OH. Dig-up and testing showed the boards still met specifications. Warm-N-Dri has been installed in Norway and Sweden for over 30 years for drainage and foundation insulation. Tests have been conducted in 1967, 1970, 1971, etc. by Gulfiber, GFB Lab LQT/USN per Drainage Sheets Summary of State Testing Facility Report SP 76401.100 Sweden. Warm-N-Dri was first installed at the Owens-Corning Fiberglas Research and Development Center in 1982.

6) What are the advantages of using the 1 3/16" Warm-N-Dri board instead of the 5/8"?

Since the 1 3/16" thickness is double that of the 5/8", the drainage capacity is doubled. Under 3' of wet sand the compression rate is 2%. The additional thickness has greater structural integrity and can withstand more construction abuse such as gouging or "dog ears". Possibly most important is that 1 3/16" Warm-N-Dri offers more thermal value to sustain the thermal environment inside the missile magazine.

We look forward to servicing your needs.

Sincerely,

OWENS-CORNING FIBERGLAS

Micheal K. Sutton
Marketing Development Manager
Foundation Systems Business

MKS/lw

cc: J. Daugherty - G-20-2
S. Schulze - T/23
M. Smith - Concrete Solutions

05018703.MKS4

OWENS CORNING
FIBERGLAS

OWENS-CORNING FIBERGLAS CORPORATION

P. O. BOX 105060, ATLANTA, GEORGIA 30348
PHONE: (404) 956-1465

May 1, 1987

Mr. Gordon Campbell
C Construction
P. O. Box 8270
Tyler, Texas 75711

Dear Mr. Campbell:

Owens Corning Fiberglas Corporation warrants that the vertical subsoil foundation of the Kings Bay Motor Missile Magazines coated with the Tuff-N-Dri® Waterproofing System shall carry a three (3) year product and 50% labor and workmanship warranty from date of installation. Concrete Solutions, our Certified Waterproofing Contractor, will be carrying the remaining 50% labor and workmanship warranty during the three year period. Should the Tuff-N-Dri® system be otherwise than as warranted, OCF will provide the necessary materials and 50% of the labor and workmanship to prevent water seepage or leakage. OCF and Concrete Solutions shall have the option of repairing either the interior or exterior of the structure.

This warranty does not apply and OCF shall not have responsibility for leakage or seepage resulting from:

1. Structural defects (including cracks of 1/8" or greater) in the walls, footings or foundations of the structure.

2. Defective or inadequate functioning of drainage system of the structure.

3. Damage to the installed systems or to walls to which it is applied.

4. Interior condensation

5. Intrusion to or alterations of the coated wall after installation.

6. Installation by a coating contractor who is not an OCF Certified Independent Waterproofing Contractor.

Any implied warranty including warranty of fitness for a particular use or purpose, or warranty of merchantability is limited in duration to the express warranty provided herein. OCF will not be responsible or liable for any damage to contents, or any other consequential or incidental costs incurred due to a water leakage problem and its remedy.

This warranty is not required by the specifications but is offered at the special request of C Construction. Such warranty should not be construed as an industry standard.

Sincerely,

OWENS CORNING FIBERGLAS

MKS:sbm

cc: Michael Smith, Concrete Solutions
Steve Schulze, T/23
John Daugherty, G-20-2

R.C.I.C.C.
KINGS BAY
GA.

2 JUN 87 08 32

LY TO

31558
6346

3212 Chandler Highway
Tyler, TX 75702
214 • 597 • 1500

June 1, 1987

CC INDUSTRIAL
AL SUBMARINE BASE
GS BAY, GEORGIA 31547 7200

FY 87 MOTOR MISSILE MAGAZINES
CONTRACT NO. N68248 84 C 4147
KINGS BAY, GEORGIA 31547
Serial No. 71
Re: Water Proofing

tlemen:

subcontractor Concrete Solutions, requested additional test be run the Warm-N-Dri Waterproofing System. The following is the results the tests for your review and/or comments:

Additional drainage tests for 1 3/16 inch Warm-N-Dri run at a hydraulic gradient of 2.3. The board was compressed 5 percent, which for wet sand corresponds to a below grade depth of 15 feet. The average drainage rate is 5.25 gallons per minute based on drainages measurements for the 1 3/16 inch and the 2 3/8 inch Warm-N-Dri. The calculated hydraulic gradient required to flow 5.0 gallons per minute through 5/8 inch Warm-N-Dri is 4.5. As mentioned, Warm-N-Dri retains its R-value after the water drains through it to the tele system. Hence 5/8, 1 3/16, and 2 3/8 inch Warm-N-Dri provides R 2.5, 5.0, and 10 thermal protection respectively.

se contact the Writer should you have any questions concerning this.

Yours truly,

C CONSTRUCTION COMPANY, INC.

yler
ile

ENCLOSURE 9

OWENS-CORNING FIBERGLAS CORPORATION

P. O. BOX 105060, ATLANTA, GEORGIA 30348
PHONE (404) 956-1465

July 23, 1987

ROICC Industrial
Kings Bay Submarine Base
Kings Bay, Georgia

Subject: Waterproofing Issues on Kings Bay Naval
Motor Missile Magazines

This memo addresses the three issues highlighted form the review of the initial installation of the Tuff-N-Dri System. Each issue will be discussed separately. It should be noted that all three issues are, in reality, appearance issues and not performance issues. Nevertheless, steps to minimize these appearance issues will be addressed.

Waterproofing material runs/sags - When spray applying Tuff-N-Dri waterproofing to a high millage (over 60 mils), a certain amount of the material will not be able to atomize or cure quickly enough resulting in some sagging or "runs". Essentially, this is excess material and a micrometer check of the area from whence the sag "came" will show the desired thickness is maintained. When the protection/drainage boards are applied, these runs are flattened out and serve as excellent adhesion points.

The amount of sag can be controlled by applying more frequent but thinner applications. However, since we feel the sags and runs actually enhance performance, more frequent but thinner coats could be a waste of labor time.

It should be noted that the Tuff-N-Dri polymer modified waterproofing is applied as delivered. It is not "cutback" or chemically modified to make it spray applicable. We do not require surface primers or waiting for concrete moisture cure, limitations which are commmon to other fluid applied coatings.

Waterproofing sags at horizontal board joints

The drainage characteristic of Warm-N-Dri is unique in that the majority of the water flow occurs in the first 1/4" - 3/8" of the board's outer surface, thereby minimizing the amount of water that reaches the waterproofing or the structure. This is im contrast to other drainage medias that actually direct water inward to the waterproofing and the structure.

When Tuff-N-Dri "sags" overlap the board joints this reinforces the surface drainage characteristic of the board. The waterproofing actually serves as a flashing to "kick" any penetrated water out to the board surface.

The amount of waterproofing spillover can be minimized by using a thicker drain board. Warm-N-Dri also comes in 4' x 8' sheets in 1 3/6" and 2 3/8" thicknesses. This will signifcantly reduce the number of seams and provide a wider drip edge to collect runs. What waterproofing that does collect will flash out drained water to the surface of the thicker board. Board edge spillover can also be reduced by working vertically to the top of the magazine as opposed to working horizontally.

Warm-N-Dri adhesion/conformance to structure shape

An application enhancement will be instituted here. The thicker boards will be serrated at 1'-2' intervals (as required) using a V shaped tool common to HVAC fiberboard installers. This serrated board (cut on the ground, prior to installation) will more closely conform to the structure's curvature. Additionally, in the hot, humid,ambient environment of Kings Bay, it is important for the board to be installed within 10-15 minutes of the final waterproofing application. Should more time expire, and board adhesion become a problem, a light spray on the waterproofing and on the board will create a strong bond.

Owens-Corning would like to reiterate that this project carries a three year limited performance warranty against leaks, mutually backed by Owens-Corning and our Certified Contractor, Concrete Solutions. The implemented aforementioned steps should minimize the above appearance concerns and provide the Navy with a high performance, dependable waterproofing system.

Sincerely,

OWENS-CORNING FIBERGLAS

MKS:sbm

07238770.TND

OWENS CORNING
FIBERGLAS

OWENS-CORNING FIBERGLAS CORPORATION
P. O. BOX 105060, ATLANTA, GEORGIA 30348
PHONE. (404) 956-1465

August 18, 1987

Lt. Tim Biggins
ROICC - Industrial
Naval Submarine Base
Kings Bay, Georgia 31547-7200

Dear Lt. Biggins:

This letter is intended for two purposes. First, it is important to denote the application and performance advantages of Tuff-N-Dri polymer modified waterproofing versus the polyurethane types. Secondly, a list of references is provided on jobs that most resemble a motor missile magazine, i.e, earth shelter housing and tunnels.

Tuff-N-Dri Waterproofing has at least the following advantages versus fluid applied urethanes:

1) Certified Contractor application - The Tuff-N-Dri system is only installed by Owens-Corning trained and certified applicators. We know when, where and how our system is being applied. Having a knowledgeable applicator is absolute to insure proper job preparation and product application. By contrast, urethanes are sold through distribution and anyone could purchase and apply them.

2) Application on green concrete - Tuff-N-Dri can be applied as soon as the forms are removed. By contrast, urethanes require a 7-28 day concrete cure time prior to application. Their specifications require a concrete moisture test that is not even applicable to Tuff-N-Dri.

3) Surface preparation - After patching honeycombs and any large tie holes, Tuff-N-Dri can be applied. No surface priming is necessary. By contrast, urethanes require a primed, smooth surface, free of any pits or voids. Lack of attention to this detailing can result in severe blistering.

4) Application on damp concrete - Urethanes require a completely dry substrate surface. Tuff-N-Dri can be applied on damp surfaces. This is especially advantageous in the humid ambient climate of Kings Bay where afternoon thundershowers are common.

ATLANTA REGIONAL/BRANCH OFFICE

5) Product preparation - Tuff-N-Dri is spray-applied, under high pressure, immediately from its containers. No mixing or other product modification is necessary. The product applied is in conformance with manufacturing specifications. By contrast, the urethane must be "cut" with a solvent to render it sprayable. Product quality control on the job site could be very difficult.

In summary, it should be discernible that Tuff-N-Dri is a better application for the motor missile magazines than a urethane. These five advantages can expedite the construction process. As soon as the applicator gains experience with the unique shape of the magazine, it should take no longer than 2 to 2 1/2 days to completely waterproof each unit. It should also be noted that this short installation time includes the drainage media.

Owens-Corning offers single source manufacturing responsibility for the waterproofing system that also includes a drainage media/protection board. The board is unique in that it also offers insulation. This attribute can reduce interior humidity and assist the surrounding soil with maintaining a constant temperature inside the magazine.

In providing additional references for the Tuff-N-Dri system, I wanted to supply structures that most resembled the magazines. What comes to mind is earth sheltered housing and underground tunnels. Earth shelter homes are probably the best reference possible due to the sensitivity of the owner to moisture penetration. Please feel free to contact any of the following:

Dr. Jim Powell, Birmingham, AL Waterproofed in 1982	205-783-5135 Mon., Tues. 205-591-2311 Wed. Th., Fri.
Ralph Josey, Griffin, GA Waterproofed January 1986 Retired Navy personnel	404-227-1225 (after 3:30)
Clifford Wagner, Woodstock, GA Waterproofed in 1983	404-475-0070
Randy Newton, Walker CRSS Stapleton Airport Tunnel Waterproofed in 1986	303-329-0321

Should you need further assistance, please don't hesitate to give me a call. John Daugherty, our Technical Supervisor, and I are available to

discuss the application of the Tuff-N-Dri System on the Motor Missile Magazines. We do feel our system provides the best application possible for your needs.

Sincerely,

OWENS-CORNING FIBERGLAS

Foundation Systems Business

MKS:sbm

cc: M. Smith, Concrete Solutions
J. Daugherty, OCF, G-20-2
Mr. Coy Rigney
C Construction
P. O. Box I.I.I.
St. Mary's, GA 31558

08188751.MKS4

OWENS-CORNING FIBERGLAS CORPORATION

P. O. BOX 105060, ATLANTA, GEORGIA 30348
PHONE, (404) 956-1465

August 18, 1987

Lt. Tim Biggins
ROICC - Industrial
Naval Submarine Base
Kings Bay, Georgia 31547-7200

Dear Lt. Biggins:

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discuss the application of the Tuff-N-Dri System on the Motor Missile Magazines. We do feel our system provides the best application possible for your needs.

Sincerely,

OWENS-CORNING FIBERGLAS

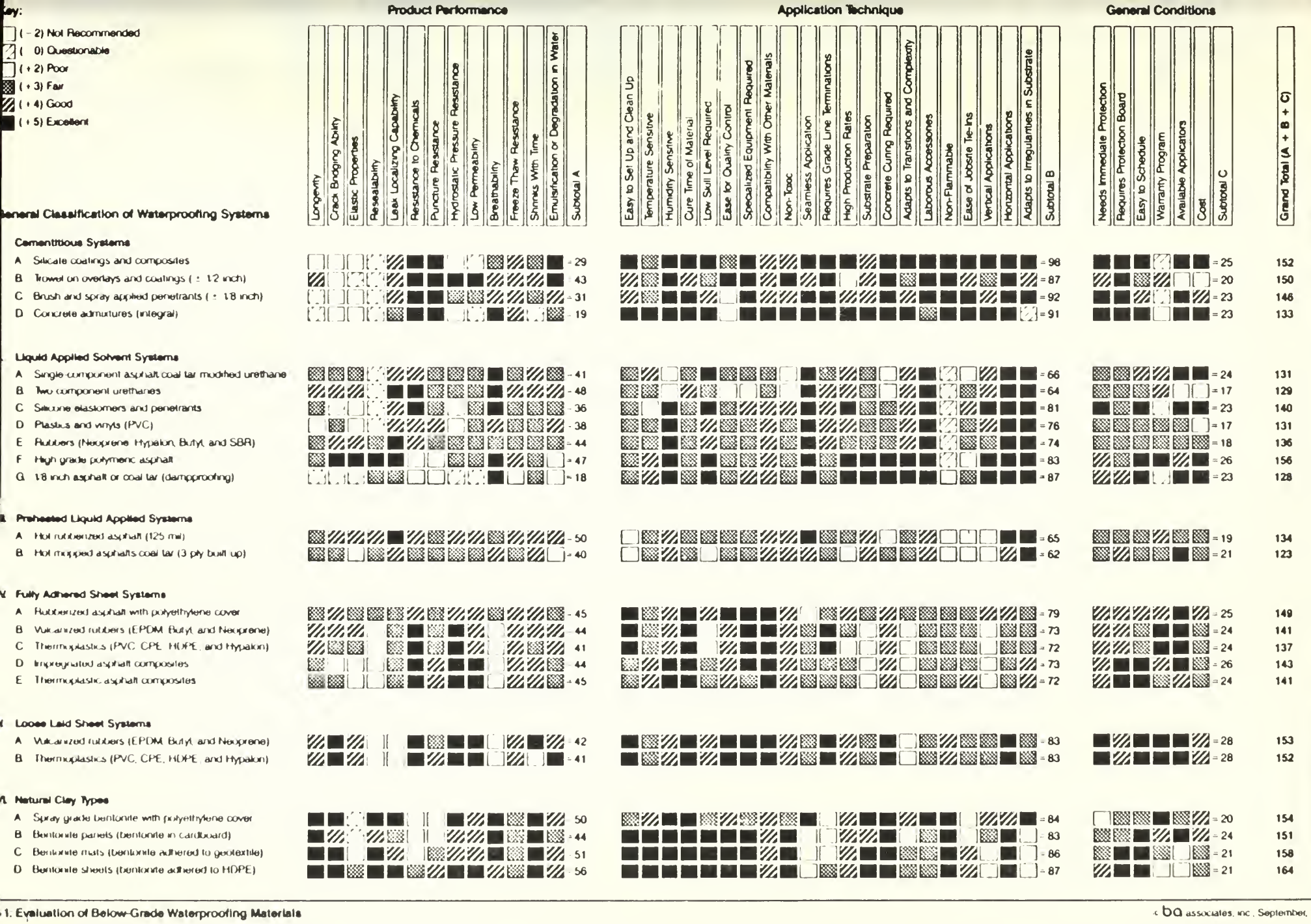
Foundation Systems

MKS:sbm

cc: M. Smith, Concrete Solutions
J. Daugherty, OCF, G-20-2
Mr. Coy Rigney
C Construction
P. O. Box I.I.I.
St. Mary's, GA 31558

08188751.MKS4

APPENDIX B



1. Evaluation of Below-Grade Waterproofing Materials

BA associates, inc.
BULLETIN

TECH-NOTE 1

LUATION OF BELOW-GRADE WATERPROOFING ERIALS

oduction

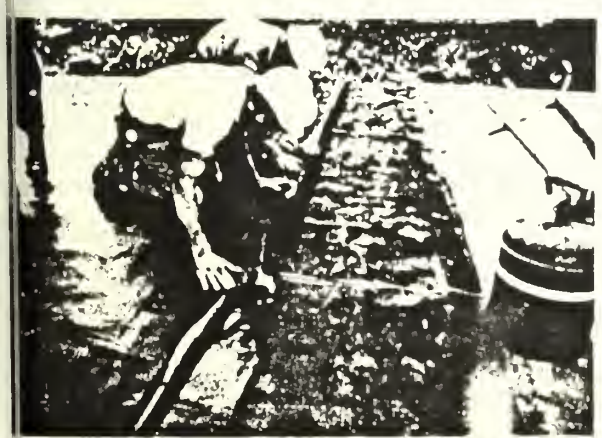
ollowing table is provided by BA Associates, Inc., as a means to are several generic waterproofing systems. The chart is based ibjective parameters coming from engineering, chemical, and experience. It is understood that the quality of one manufactur- roduct may vary significantly from another's within the same cat- . Furthermore, note that some criteria are not valid for certain proofing jobs (i.e., those being concerned with low temperature hole working in Hawaii, or freeze-thaw resistance in Southern rnia). Therefore, do not base your decisions solely on a final er, but analyze a product's relative position for the most impor- riteria.

valuations are broken down into three categories:

(1) Product performance criteria;
(2) Application technique criteria; and
(3) General condition criteria.

ner, architect, waterproofing contractor, or the general contrac- ay find these criteria helpful when evaluating a particular job. It also be true that certain criteria should have much higher or designations than others, such as cost, warranty, and longevity.

IPROOFING TYPE: Spray Systems



ROOFING TYPE: Loose Laid Single-Plys

Definitions

Longevity– this concept is very subjective. These conditions are based on wet/dry, as well as, freeze/thaw cycles that exist in most parts of the country. Horizontal surfaces with ponded water are the most severe. Products not only must last, but maintain their physical characteristics over the years.

Range	Variable
Highly variable	-2
1 to 5 years	0
5 to 10 years	2
5 to 15 years	3
10 to 30 years	4
20 to 50 years	5

Crack Bridging Ability– able to bridge + 1/8 inch crack over repeated cycles at various temperatures over extended periods of time.

Elastic Properties– can maintain 300% elongation for extended periods of time in various temperature ranges.

Resealability– able to reseal cracks + 1/8 inch or smaller which occur after application, and are subject to repeated movement.

Leak Localizing Capability– ability to control water migration on the substrate if water bypasses the membrane; the best systems are directly adhered to the substrate.

Resistance to Chemicals– long-term resistance to salts, soil acids, methane, fertilizers, sulfates, and other soil constituents. Most product testing and product literature are quite vague in this area.

Puncture Resistance–ability to resist jobsite damage, rough irregular substrates, and coarse backfill materials; this concept is very *subjective*.

Hydrostatic Pressure Resistance– ability to withstand heads of 50 feet or higher for extended periods of time, especially at the seams.

Low Permeability– has good water impedance characteristics at high heads, under wet/dry and hot/cold conditions, and seasonal cycles. Seams and joints are the controlling factors; laboratory testing only shows the ideal or near perfect conditions.

Breathability– will pass water vapor but not liquid water; important for condensation purposes, and is subject to much debate.

Freeze/Thaw Resistance– ability to withstand hot and cold cycles; low sensitivity to thermal gradients. Relates to concrete substrate as well as membrane.

Shrinks With Time– subject to pin holes and cracking as solvents and or plasticizers migrate our of the material. Varies considerably from manufacturer to manufacturer.

Subject to Emulsification or Degradation From Water– can the material withstand long-term exposure to water (the universal solvent) without chemical physical breakdown? Physical breakdown is seen in long-term brittleness, and chemical breakdown is generally shown by loss of material as it is dissolved in water.

Easy to Set Up and Clean Up– waterproofing applicators like materials that easily wash off their skin, and do not mess the jobsite or drift

wind; sticking to nearby cars, buildings, or glazed areas.

erature Sensitive– the working range of a waterproofing prod- ould be + 10°F to + 100°F. Above or below these temperatures, ield people do not care to work.

dity Sensitive– waterproofing products should be insensitive nidity changes between 30 to 70 percent. Cold concrete subs are many times dampened by condensation from the air when w point is reached. This aspect must be closely watched with products.

Time of Material– materials that can be backfilled immediately pplication are ideal. Less material exposure to jobsite damage, olet radiation, rain, snow, or high winds maintains their integrity ack jobs also require products that cure quickly, especially in eather.

Skill Level Required– the "K.I.S.S." principle holds true for roofing products. Jobsite mixing, specialized heat welding, g, and cutting tend to cause problems when cold weather con- , job delays, or manpower shortages exist.

for Quality Control– providing a uniform thickness and ght seams are two of the most important areas for product ation.

ilized Equipment Required– waterproofing applicators prefer mechanical equipment which tends to breakdown less, thus ng job delays. Equipment increases overhead costs for opera- d has difficulty maneuvering around many jobsites.

atibility With Other Materials– it is important that solvents, e agents, or base materials are compatible with insulation, ge boards, or protection courses. Incompatibilities can cause lays until proper curing has taken place. It is becoming more on for composite waterproofing systems to be used incorporat- advantages of both sheet and spray systems.

oxic– environmental awareness, as well as human life-safety ns, are growing, as evidenced by the use of petroleum based ts, silicates, and isocyanates on projects.

ess Application– rarely are large waterproofing jobs com- without seams. Liquid-applied systems offer the lowest seams e of their nature, as well as the ability to integrally bond to elves. Cured sheet systems depend upon solvent, heat or ves to provide a watertight bond. These bonds are rarely equal base material, except in some circumstances, where heat weld- ised.

es Grade Line Terminations– almost all products require ine terminations. Ultraviolet radiation exposure, hot cold, wet les, and mechanical abrasion due to landscaping, all contrib- membrane breakdown at the exposed grade line. Termination waterproofing system below the grade line is irresponsible mar- by a product manufacturer. Waterproofing products should al- xtend one to eight inches above the grade line.

roduction Rates– this allows the waterproofing applicator to n and quickly move-on, reducing job delays and scheduling ns.

ate Preparation– this concept is seriously overlooked by most cts and general contractors. Too often waterproofing ap- s are psychologically forced by the general contractor into g products onto improper substrates. This is one of the lead- ses of leaks and membrane failures.

ete Curing Required– most waterproofing products require a day cure on poured concrete surfaces before application. This elp preserve material bonding properties. Liquid-applied and ystems are subject to blistering and pin holes if excess curing scapes the concrete after waterproofing application. Many di dhered sheet systems are also susceptible to blistering, and ebonding as excess water vapor escapes the cor

to Transitions and Complexity– spray and l applied products function best in these environments because they bond directly to the substrate and can conform to irregular surfaces. Sheet system failures usually occur in these areas because of all the cutting and gluing (i.e., seaming) required.

Laborous Accessories– many sheet and panel systems require extensive amounts of patching, joint mastics, lap sealants, and other tasks to complete the system. Architects must properly specify these materials and assure their proper installation.

Non-Flammable– safety is always a major concern on a construction jobsite. Systems which do not require petroleum-based adhesives and solvents stand much less of a chance to be a fire hazard.

Ease of Jobsite Tie-Ins– unimportant as it seems, this can be a frustrating problem for field people. Waterproofing is usually done in 8 to 12 foot lifts and 40 to 80 foot lateral sections. Tie-ins (field seams) typically occur at construction joints, where both the waterproofing and concrete structure are least watertight.

Vertical Application– ease at which the product can be applied. Some products are developed for vertical use, while others are for horizontal use. Yet many times, they are used on all surfaces.

Horizontal Application– ease at which the product can be applied. Hot and self-leveling products are well adapted for this application. Their use vertically is usually dangerous and difficult to achieve quality control.

Adapts to Irregularities in Substrate– rarely is a concrete substrate like that shown on the drawings or as envisioned by the waterproofing contractor during bidding. Form line ridges, tieback holes, blow-outs, construction joints, honeycombing, pour lines, and surface dust all contribute to an irregular substrate. The waterproofing product must adapt to this everyday, real world situation; liquid or spray systems seem to be best suited.

Needs Immediate Protection– sheet systems tend to outperform sprays because of their inherent strength and cured qualities. Backfilling sequences almost always tend to require some waterproofing products to standout for long periods of time. Bentonite clay systems offer severe limitations if required to stand unprotected for long periods of time.

Requires Protection Board– other than cementitious systems, almost all waterproofing products require some protection from backfilling. Only under conditions where clean, uniform sand is used for backfilling should products go unprotected.

Easy to Schedule– this concept is best suited by products that require little jobsite protection, and no special curing of the concrete substrate or waterproofing product. This is important on fast-track jobs.

Warranty Program– few manufacturers have a strong warranty program. Most warrant their material to be good while still in a warehouse. However, once it hits the job, it becomes the applicator's responsibility. Most manufacturers will only replace material proven to be defective, and not cover any repair costs. An owner's warranty is generally in the hands of the applicator.

Available Applicators– before specifying a product, the architect should be assured he or she will receive competitive bids from two or more applicators.

Cost (The Bottom Line)– despite all the pros and cons, the product must be competitive. This does not mean "lowest cost is best"–but the value added products must be justified.

Contact BA Associates, Inc., for any further literature or questions about the information provided.

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